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EFFECT OF ROOM GEOMETRY ON THE TRANSMISSION LOSS OF PANELS

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A Thesis
in the
Centre for Building Studies
Faculty of Engineering

Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering at
Concordia University
Montreal, Quebec, Canada

November 1981

ABSTRACT

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An experimental investigation of parameters that may affect the transmission loss of panels is presented in this report. These experiments were carried out following studies documenting differences that exist between laboratories on the measured transmission loss of partitions.

To minimize the spread in results between laboratories one must first understand how and which parameters affect the transmission loss of partitions. Then guidelines can be set for laboratories to follow in order to achieve minimum differences in transmission loss results.

The parameters considered in this study include panel sizes, room dimensions, mounting orientation and diffusing conditions. Tests were conducted for double gyprock, single gyprock and glass panels.

The results indicate that panel area and mounting orientation have a definite effect on the measured transmission loss. Varying the room volume shows slight dependence, whereas the amount of diffusion indicates minimal effect on the measured transmission loss above the cut-off frequency.

From the results obtained a series of guidelines evolved from which additional tests can be run in other laboratories to gather sufficient data in order to derive appropriate normalization procedures so that transmission loss measurements can be made to better agree between the various laboratories.

ACKNOWLEDGEMENTS

I wish to express my sincere thanks to my supervisor and advisor, Dr. M. A. Lang, for his guidance, help and financial support under NSERC Grant No. A9193 throughout this study.

Special thanks go to J. Zilka, Laboratory Technician, who aided me on numerous occasions during the experiments.

I would also like to thank my special friends at the Centre for their help and encouragements, as well as my parents for their patience and understanding, and G. Miller for the typing of the manuscript.

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NOMENCLATURE

a	Student's t-distribution for observations greater than 25 measurements
A_r	absorption in receiving room, metric sabins
B	bending stiffness per unit width of panel, N-m
B_r	bandwidth of typical mode
c	speed of sound in air, m/s
d	rate of decay of a mode, dB/s
d_j	individual measurement in SD calculations
$\bar{d}$	mean of j individual measurements
E	Young's Modulus, N/m^2
f	frequency, Hz
f_c	critical frequency, Hz
f_n	natural frequency, Hz
$f_{c,s}$	Schroeder cut-off frequency, Hz
h	panel thickness, m
j	complex number
k_x, k_y, k_z	wave numbers in x,y and z directions
l_x, l_y, l_z	dimensions of rooms along axis, m
L	sum of lengths of room edges, m
L_{cR}	corrected sound pressure level, dB
L_R	sound pressure level in receiving room, dB
L_B	background level in receiving room, dB
m	mass of panel, kg/m^2
M	Modal Overlap Index
n_x, n_y, n_z	positive integers
n	number of measurements
N	mode number
NR	noise reduction, dB

ΔN	modal density
p	acoustic pressure, N/m^2
p_o	reference pressure, N/m^2
P	pressure magnitude
R	measured range of decay
S	surface area, m^2
S_c	composite wall surface area, m^2
S_i	surface of ith section, m^2
S_p	panel surface area, m^2
S_R	$S_c - S_p$, m^2
SPL	sound pressure level, dB
SPL_t	SPL in transmitting room, dB
SPL_r	SPL in receiving room, dB
SD	standard deviation
t	time, sec
TL	transmission loss, dB
TL_o	TL for sound waves incident normal to panel, dB
TL_p	TL of panel, dB
TL_c	TL of composite wall, dB
TL_R	TL of reference wall, dB
T	temperature, ^oC
T_d	average time for decay range, sec
T_{60}	reverberation time, sec
V	room volume, m^3
x,y,z	room dimensions, m
η	panel loss factor
λ	wavelength, m
ρ	density of air, kg/m^3
ρ_s	mass of material per unit area, kg/m^2
τ_c	transmission coefficient of composite wall
τ_i	transmission coefficient of ith section
ω	angular frequency, rad/sec

CHAPTER I

INTRODUCTION

When considering noise within the built environment, special attention must be given to user needs and requirements such that undesired noise levels are brought down to minimum standards to best serve room functions. The parameters that should be taken into consideration include shape and size of rooms, orientation of the rooms within the building and the selection and placement of absorptive and reflective materials to provide the best conditions for the growth, decay and steady-state distribution of sound in rooms.

Rooms are formed when a space is enclosed by four walls, a roof and floor, which can be constructed from a variety of materials. The type of wall construction will dictate to what extent sound from within the enclosure will be transmitted to an adjacent enclosure.

A good wall is said to have a high transmission loss, where sound waves impinging on one side of it are attenuated such that there is little transmission through to the other side.

Whereas a particular wall may have a high transmission loss, this characteristic is not sufficient in itself to ensure that sound will not be transmitted to the other side. Poor construction such as improper peripheral sealing, among many others, can greatly decrease the performance of the wall.

To obtain quantitative data on the transmission loss of a particular wall construction tests are conducted in reverberation suites where the particular panels to be tested are placed in an aperture between two adjacent chambers with known acoustical properties. It is found through experimental data and supported by theoretical analysis, that the transmission loss of a wall or panel is dependent on boundary conditions such as wall and room dimensions, boundary conditions for the panel, loss factors of both panel and rooms as well as sound-source[1] location.

Though useful information on the behaviour of sound in enclosures and the acoustical performance of building materials is provided by laboratories, there exists a lack of agreement in measured transmission loss values both between laboratory and field measurements as well as between laboratories[2].

This chapter begins with a brief introduction on the sound transmission loss of a wall, followed by a discussion of factors that might affect interlaboratory results. A brief account of the tests performed in the reverberation chamber at the Centre for Building Studies, Concordia University, is discussed. Finally the organization of the text is presented.

It has been shown that transmission loss results vary from laboratory to laboratory even when the variation in test material parameters are minimal and as well when the restraint conditions of the panels are the same[3]. The conclusion drawn from such results is that some other parameters are affecting the measured transmission loss of panels. The first objective of the research project which leads to the experimental work presented here is therefore to determine which parameters could possibly have an effect on the transmission loss of panels. The parameters investigated included room volume, panel sizes, sill sizes, panel position within the aperture and diffusing conditions in the chambers.

The second objective will be to present guidelines for testing chambers so that the spread in transmission loss results of the various laboratories can be reduced.

CHAPTER I

1.1 SOUND TRANSMISSION LOSS OF A PARTITION

Walls between adjacent rooms are rated for the amount of insulation they can provide against noise. The transmission loss, TL, of a partition is an indication of how well a wall provides this sound insulation. A typical TL curve as a function of frequency is illustrated in Fig. 1.1, in which three regions can be identified. Region I is the stiffness controlled region where the TL of the panel is dependent on its stiffness at low frequencies. In this region there is a 6 dB decrease for doubling of frequency. At resonance, just before the mass controlled region there is a 6 dB increase for doubling of damping.

Region II, the mass controlled region is separated from the stiffness controlled region by the lowest resonant frequency of the panel in bending. This frequency will be defined in a later section. The mass controlled region is a function of the mass of the panel. In this region stiffness and damping are not important and the transmission loss of the panel can be calculated by the expression[19],

$$TL = 10 \log \left[1 + \left(\frac{\omega m}{2\rho c}\right)^2\right] \qquad (1.1)$$

where ω = angular frequency = $2\pi f$, rad/sec

m = mass of the panel per unit area, kg/m^2

ρc = the characteristic impedance of air, kg/m^{2}s

for normal incidence, which is called the "mass law" where the TL increases at a rate of 6 dB per doubling of either the mass or the frequency.

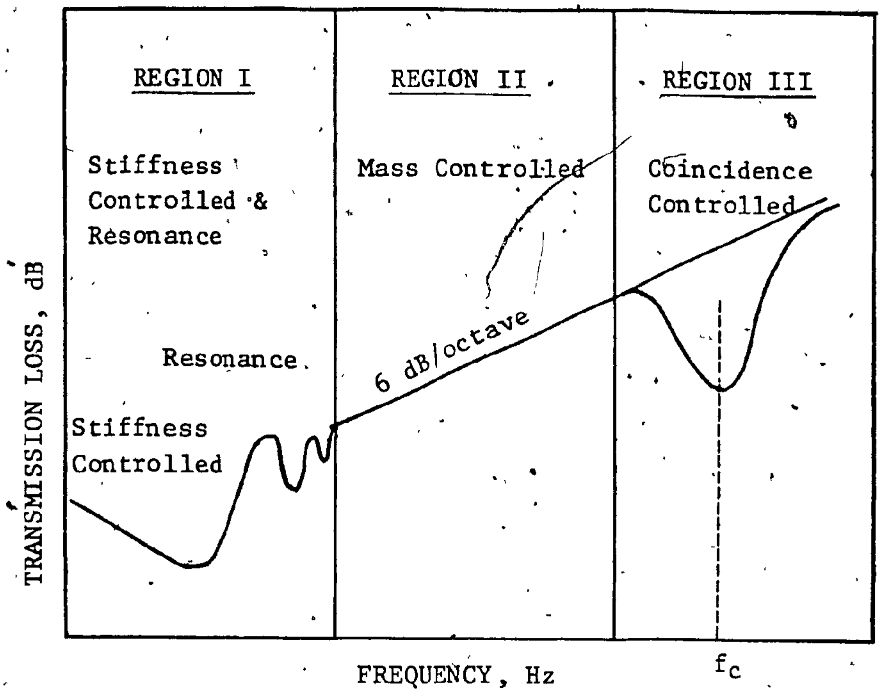


FIG. 1.1 Typical transmission loss curve showing the three regions of transmission loss performance of a wall. f_c is the critical frequency.

The coincidence controlled region, Region III, is the region where the TL values diverge below those predicted by the mass law, reaching a minimum at the critical frequency, f_c. At this frequency the panel bending wavelength equals the trace wavelength of grazing acoustic waves, increasing panel vibration. When the panel vibration is high, transmission through the panel increases, thus resulting in a lower TL. Above the critical frequency the TL increases. When the sound in two rooms approaches a diffuse field, i.e. the intensity of the sound is equal in all directions throughout the room, and providing the sound is transmitted only through the dividing wall, the TL of the wall can be calculated knowing the sound pressure levels in each room as well as the absorption in the receiving room. The method by which these quantities are obtained will be discussed in Chapter II.

Therefore, the TL as a function of frequency is found from:

$$TL = NR - 10 \log A_r/S \qquad (1.2)$$

where $NR = SPL_t - SPL_r$ = the average sound pressure difference between rooms. That is, the difference in sound pressure levels between the transmitting and receiving room, dB

S = area of dividing wall , m^2

A_r = equivalent absorption area of the receiving room determined from reverberation measurements, metric sabins.

To approximate diffuse field conditions the following requirements have to be met:

a) There must be a sufficient number of room resonances (modes) within a test band.

b) The modes i.e., the natural vibration of air in a room when subjected to an acoustical disturbance, must be distributed as uniformly as possible over the band.

c) The direction of propagation of the modes must be uniformly distributed throughout the room.

d) The modes should have sufficient bandwidth.

The first two requirements depend on room dimensions (as shown in Section 1.2.3). The dimensions and shapes of the room should not be exactly the same since the more symmetrical a room becomes the more irregular its modal response becomes, whereas irregular walls tend to give more uniform distribution of the sound energy. It is recommended that room volumes should not be less than $4\lambda^3$ where λ is the wavelength of the middle frequency of the lowest band of interest[5]. Room volumes down to half the value of $4\lambda^3$ are permitted in various standards[5,11].

The third requirement is a function of the room absorption and on the nature of diffusing surfaces in the room. Low frequency absorption is usually required where there are fewer room modes per test band. By increasing the low frequency absorption the modal responses of the low frequency modes are broadened thus improving modal overlap. At the higher frequencies the absorption in the room should be low.

Diffusing surfaces can be either stationary or rotating. Stationary diffusers are large panels usually having shapes which are irregularly curved. To adequately diffuse the sound field, the panels are suspended from ceilings or placed at room boundaries in a random orientation. The panels should have a width of at least ¼ λ at the lowest test band to be effective[5]. Rotating diffusers, in effect, act as modulators during determination of the average SPL by continually varying the coupling between room modes thus increasing the energy transfer between modes.

The last requirement is a function of the bandwidth of the test signal, being more stringent for narrow band signals.

The fundamental concepts of sound transmission through a panel are described more completely in the literature and expressions are derived for the transmission loss of single panels as well as multiple panels based on the mass - law theories [4,6,7,8,].

The TL of a wall calculated through Eq. 1.2 is a measured quantity and whereas S can be easily determined, problems in measurement are associated with NR and A_r where room characteristics greatly influence the measured TL. For this reason difficulties exist in matching results between laboratories. As well, there exist difficulties in calculating TL for anything but simple walls.

This thesis is primarily an investigation of geometric effects on the measured TL. To actually predict performance of walls when used in buildings further work will be required but only after differences that occur even in "ideal" lab conditions can be explained.

1.2 FACTORS AFFECTING MEASUREMENTS OF SOUND TRANSMISSION

Experimental work performed on the transmission loss of a building partition has indicated that measurements tend to be non-repeatable between laboratories using similar panels (1,2,3,9,10).

This would imply that apart from panel dimensions and material characteristics other room parameters can affect the apparent noise reduction. Among the possibilities, mounting conditions, room dimensions and amount of diffusion in the rooms are predominant. Sills and/or reveals might also be a contributing factor in the influencing of TL values.

1.2.1 SIZE OF PARTITION

Ideally a partition should extend from wall to wall and from ceiling to floor as in normal construction methods. ASTM E 90[5] recommends that the smallest dimension of a wall be not less than 2.4 m (excluding thickness) and ISO 140/I [11] suggests a wall area of $10m^2$. Construction of a wall to meet either of the above recommendations would imply small room volumes. According to standards[5, 11], larger volumes are recommended where noise measurements are to be accurate at lower frequencies. What is usually done is to mount the desired partition which will typify a wall or window in an apperture. There is no standard apperture in current usage and therefore this might be another factor contributing to non-repeatability of measurements between laboratories.

1.2.2. MOUNTING

Transmission results will vary depending on mounting conditions. As reported by Sewell [12], below the critical frequency the calculated transmission loss is about 3 dB higher for a partition surrounded by an infinite baffle that is simply supported at the edges than that of one with clamped edges. Nilsson[1] supports these results for a partition in finite surrounds. Above the critical frequency it is shown that boundary conditions do not affect TL values if edge losses are zero. But since edge losses do occur, and the panels power flow is dependent on the coupling between the panel and the adjoining structures, then it can be concluded that the firmly mounted panel will have larger losses due to power flow at the edges than will the same panel when elastically mounted. In the series of experiments reported herein the panel was simply supported throughout. The method of support will be described in Chapter II.

1.2.3 ROOM - VOLUME AND BOUNDARY CONDITIONS

For every room there exist distinct resonant frequencies also referred to as normal modes of vibration[4]. These occur when a sound ray reflected from a wall, or from successive walls, reaches its point of origin and again repeats itself creating a standing wave. If the two waves are out of phase they might partially or totally cancel each other out. If they are in phase, that is, if the path length of the wave is equal to an integer multiple of the wavelength, then they will reinforce one another. Resonance will occur at the frequency of the particular wavelength, resulting in high amplitudes.

The behaviour of sound in an enclosure is based on its natural modes of vibration, i.e. wave acoustics or wave motion of sound in a three dimensional bounded space [4]. The wave equation in three dimensions is written for the acoustical pressure in the form of[1]:

$$\nabla^2 p = \frac{\partial^2 p}{\partial x^2} + \frac{\partial^2 p}{\partial y^2} + \frac{\partial^2 p}{\partial z^2} = \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} \qquad (1.3)$$

where p = the acoustical pressure, that is, the difference in pressure between the instantaneous pressure and the time average pressure.

When the initial time boundary conditions are known, a solution of the appropriate wave equation is obtained for the particular room, describing the transient and steady state behaviour of the sound field. A brief explanation on how it is possible to use the simplest boundary condition, that of perfectly rigid walls, follows.

A sound source will excite many of the different normal modes of vibration of an enclosure. When the source is suddenly shut off the modes will start to decay in a stepwise fashion dependent on the absorbing characteristics of the room. At the lower frequencies where the number of modes is relatively small, effects of damping will be more pronounced than at higher frequencies. The characteristic frequencies of vibration depend mainly on the size of the room whereas damping rates depend on the boundary conditions. It is desirable, therefore, mathematically, when deriving expressions for characteristic frequencies, to have zero particle velocity at each wall, ie., perfectly rigid walls. Applying these boundary conditions, the general wave equation can be solved to yield the standing wave equation[4],

$$p = P\,(\cos k_x x \cos k_y y \cos k_z z)\,e^{j\omega t} \qquad (1.4)$$

where P is the pressure magnitude

k_x, k_y, k_z the wave numbers satisfying $k = \frac{\omega}{c} = \sqrt{k_x^2+k_y^2+k_z^2}$

where ω = angular frequency, rad/sec

c = speed of sound, m/s

x, y, z are the room dimensions, m

j is the complex number = $\sqrt{-1}$

t is the time, sec

from which the characteristic frequencies corresponding to the normal modes of vibration within a room are:

$$f_n = \frac{c}{2}\left[\left(\frac{n_x}{l_x}\right)^2 + \left(\frac{n_y}{l_y}\right)^2 + \left(\frac{n_z}{l_z}\right)^2\right]^{\frac{1}{2}} \tag{1.5}$$

where n_x, n_y and n_z = integers

l_x, l_y, l_z = dimensions of room along axes, m

c = speed of sound, m/s

The normal modes of vibration within an enclosure can be separated into three groups. The first group are called axial modes (one-dimensional modes) moving parallel to one axis and occur when one of the n_i are non-zero and the other two equal zero. The second group where two n_i are non-zero and the third n_i is equal to zero are known as the tangential modes (two-dimensional) moving in one of the major planes of the room. The third group are called oblique modes (three-dimensional) which are oblique to all pairs of walls. Here all the n_i have non-zero values.

If there are insufficient normal modes within a frequency band, then an adequately diffuse field, where sound energy is equally probable in all directions and uniformly distributed throughout the room, will not be attained as large spatial differences in SPL can be measured. This problem is particularly important for the lower frequencies where the number of modes is not as high as for that of higher frequencies. The number of modes which can exist below a given frequency or within a specified frequency band can be expressed as[4]:

$$N = \frac{4\pi V}{3c^3} f^3 + \frac{\pi S}{4c^2} f^2 + \frac{L}{8c} f \tag{1.6}$$

where c = speed of sound, m/s

N = number of modes below frequency f

V = volume of room, m^3

S = total wall surface area = $2(l_x l_y + l_y l_z + l_x l_z)$, m^2

L = sum of lengths of room edges = $4(l_x + l_y + l_z)$, m

f = frequency , Hz

By differentiating the above equation, the modal density, that is, the number of modes ΔN in a given frequency band Δf centered on f is:

$$\Delta N = [4\pi V \left(\frac{f}{c}\right)^3 + \frac{\pi S}{2}\left(\frac{f}{c}\right)^2 + \frac{L}{8}\left(\frac{f}{c}\right)] \frac{\Delta f}{f} \tag{1.7}$$

The above equation indicates that as the frequency and volume are increased there is a rapid increase in the number of modes in a frequency band. When the number of modes in each of the desired frequency bands is increased, a more random sound field will occur.

1.2.4 ROOM DIFFUSION

To achieve diffuse conditions the modes must be uniformly spaced in frequency, since a diffuse field depends on the modal structure of a room. As well, for a statistically reliable reverberant field at the lowest frequency of interest, there should be a suitable number of room resonances (normal modes) within a test band.

The lowest frequency at which a reverberant field can be considered as being statistically reliable is called the "Schroeder Cut-off Frequency", $f_{c,s}$, given by[6]:

$$f_{c,s} = 1200\,(M\,\frac{T_{60}}{V})^{\frac{1}{2}} \qquad (1.8)$$

where T_{60} is the reverberation time, sec

V is the room volume, m^3

$M = B_r.\Delta N$, the Modal Overlap Index where B_r is the bandwidth of a typical mode.

Though various values of M have been shown to be adequate in providing good modal overlap, the one commonly used is that suggested by Schroeder, where M = 3, in the calculation of the cut-off frequency. This value indicates that the spacing between modes is less than 1/3 bandwidth of a typical mode. Analysis of Eq. 1.8 indicates that if a lower cut-off frequency is required then either the volume will have to be increased, or the reverberation time decreased. It is usually not advisable to decrease the reverberation time by increasing absorption, since by doing so, the desired pressure levels within the room could be difficult to produce. In a room the interchange of energy between modes can be increased by placing objects within the room that scatter and therefore randomize the directions of the sound waves. These are known as diffusing elements which can be either stationary or rotating vanes. Another technique is through the use of absorptive treatment at low frequencies to increase the modal bandwidth.

1.3 TESTS PERFORMED AT CBS

The intent of this study is to analyze the effect of altering the room parameters on measured transmission loss of panels. Since most problems are found at the lower end of the frequency scale, special attention is given to diffusion characteristics at the low frequencies.

All tests were performed to satisfy the procedures of ASTM Designation: E 90-75 Standard Method for "Laboratory Measurement of Airborne - Sound Transmission Loss of Building Partitions"[5]. However, due to the smaller room volume of the reverberation chamber at CBS the tests do not comply fully with the above standard. The transmission loss was measured for three panel types:

1. glass panel
2. single gyprock panel

and 3. double gyprock panel

The four parameters considered were:

1. Two room volumes
2. Diffuse and non diffuse field conditions
3. Three panel sizes
4. Mounting position

A one third octave bandwidth with center frequencies from 100 to 5000 Hz and a random noise sound signal was used for measurements. For each experimental set-up the reverberation time, for the frequency range in question, was recorded, from which the absorption was calculated. The next step was the measurement of the space averaged sound pressure levels in both transmission and receiving rooms. Once these were recorded, the transmission loss of a particular panel, subjected to the various parameters, was calculated from Eq. 1.2. A more detailed description of the test procedure is presented in Chapter II.

1.4 ORGANIZATION OF TEXT

The text is arranged in the following manner:

a) Chapter II deals with a detailed description of the experimental set up and test procedure.

b) Chapter III deals with the analysis of the data

c) Chapter IV presents conclusions of the investigation.

CHAPTER II

EXPERIMENTAL SET-UP AND TEST PROCEDURE

2.1 THE TRANSMISSION LOSS SUITE

The facility used to perform the testing is located on the third floor of the Centre for Building Studies at Concordia University. Two adjacent testing rooms, rectangular in shape, one with a volume of about 94 cubic meters which for convenience will be referred to as room A, the other about 37 cubic meters referred to as room B, make up the transmission loss suite. The construction details of the suite[13] and the qualification for sound power testing of the reverberation chamber (room A) have previously been reported[14].

Figure 2.1 shows the actual dimensions and layout of the chambers. The walls of the chamber are of a 228mm thick staggered stud/gyprock construction. The outer layer is 12.7mm gyprock fixed on spring clips. The inner layer consists of 12.7mm and 15.87mm gyprock. The cavity is filled with fiberglass insulation. The ceiling is similar in construction except that it is suspended from the building structure on resilient hangers. A 0.81mm aluminum sheet covers both walls and ceiling, while the floor is a 101.6mm thick concrete slab, isolated from the building structure on fiberglass isolation pads. The details of the construction are illustrated in Fig. 2.2.

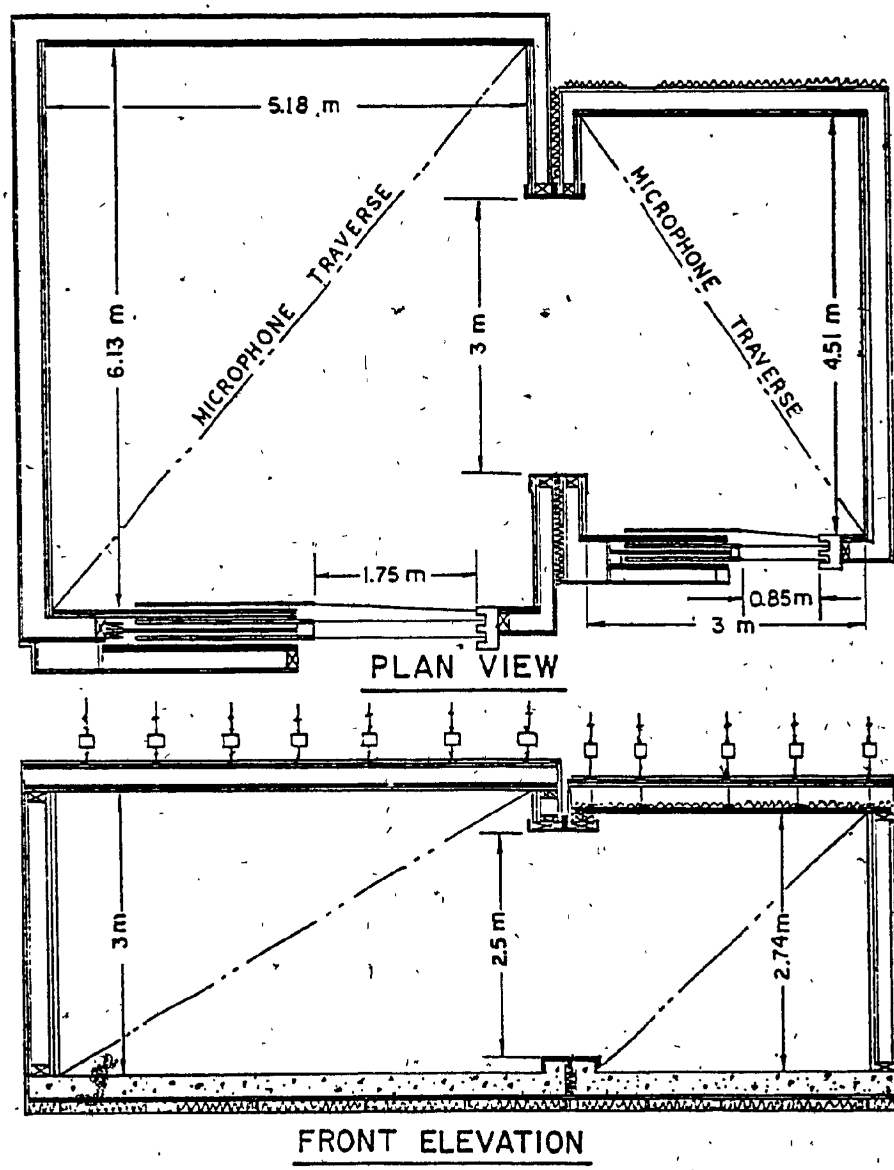


FIG. 2.1 Transmission Loss Suite at C.B.S.,Concordia U.
Plan and front elevation.

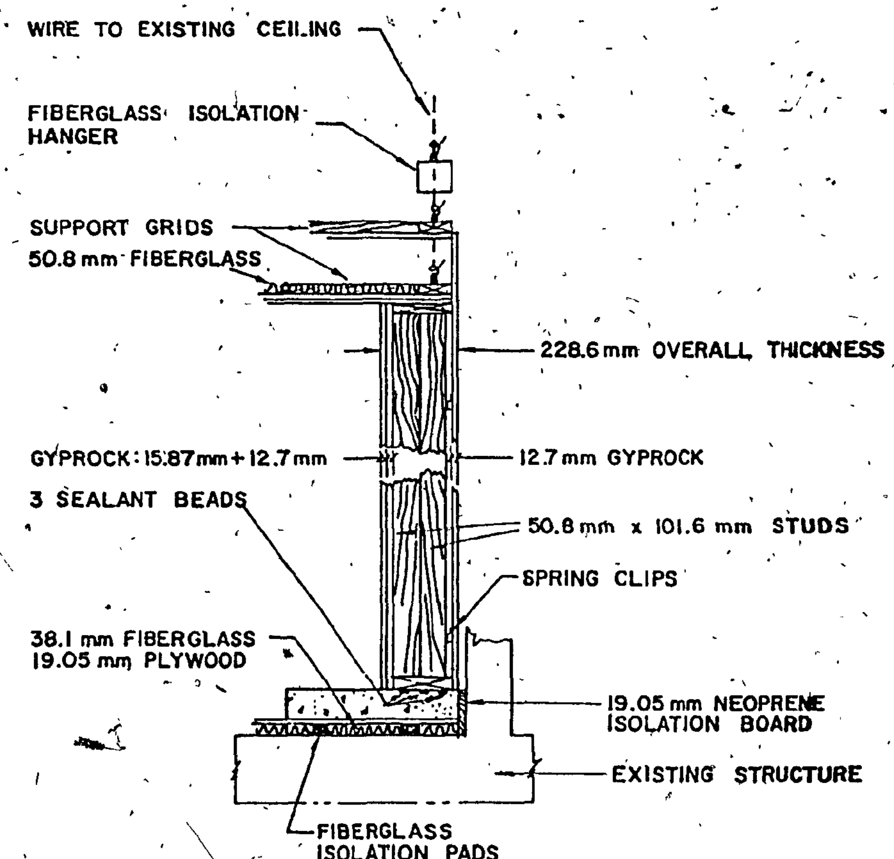


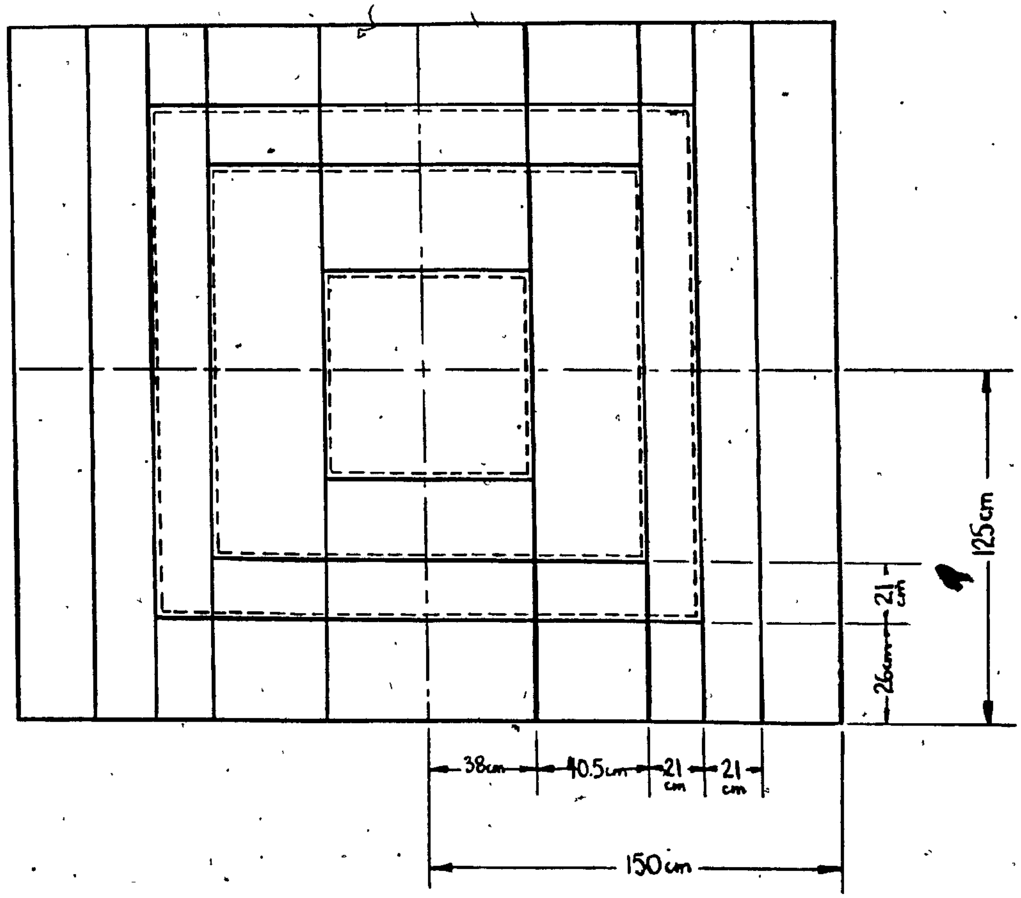
FIG. 2.2 Construction details of enclosure.

There is a 3 x 2.5m opening between the rooms where what will henceforth be referred to as the "reference wall" was built. This wall was constructed in such a fashion as to facilitate placement of the various size panels.

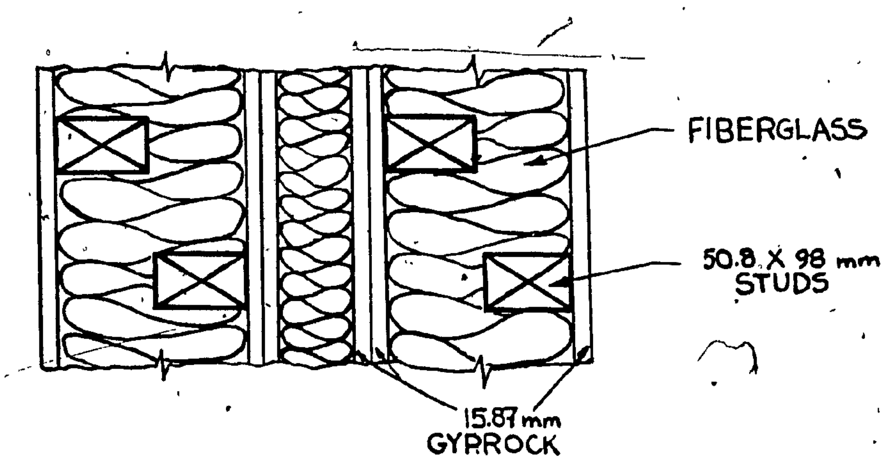
The frame of the reference wall is shown in Fig. 2.3(a). The reference wall was made up of two 228.6mm walls with a fiberglass filled cavity between them, measuring 50.8mm, ie. the cavity being the separation between the two rooms. Each wall was constructed of 5 x 10m studs, their spacing as shown in Fig. 2.3(a), covered on the outer side by two 15.87mm gyprock panels. On the inner side a 15.87mm gyprock panel was attached to the studs and the cavity filled with fibreglass insulation. Fig. 2.3(b) is a schematic of the reference wall. Access to each room is furnished through an arrangement of triple solid wood sliding doors. Rubber gaskets and neoprene skirts on the top and bottom of the doors provide for further insulation.

2.2 INSTRUMENTATION SYSTEM

The instrumentation system, divided into three subsystems, Fig. 2.4, consists of the measurement system, the control system and the output system. The measurement system is controlled by a HP 9825A desk-top computer which is connected to the printer and plotter of the output system. The equipment belonging to each subsystem is shown in Fig. 2.4, with the function of each explained below.



(a)



(b)

FIG. 2.3 Reference wall frame (a) and construction details (b).

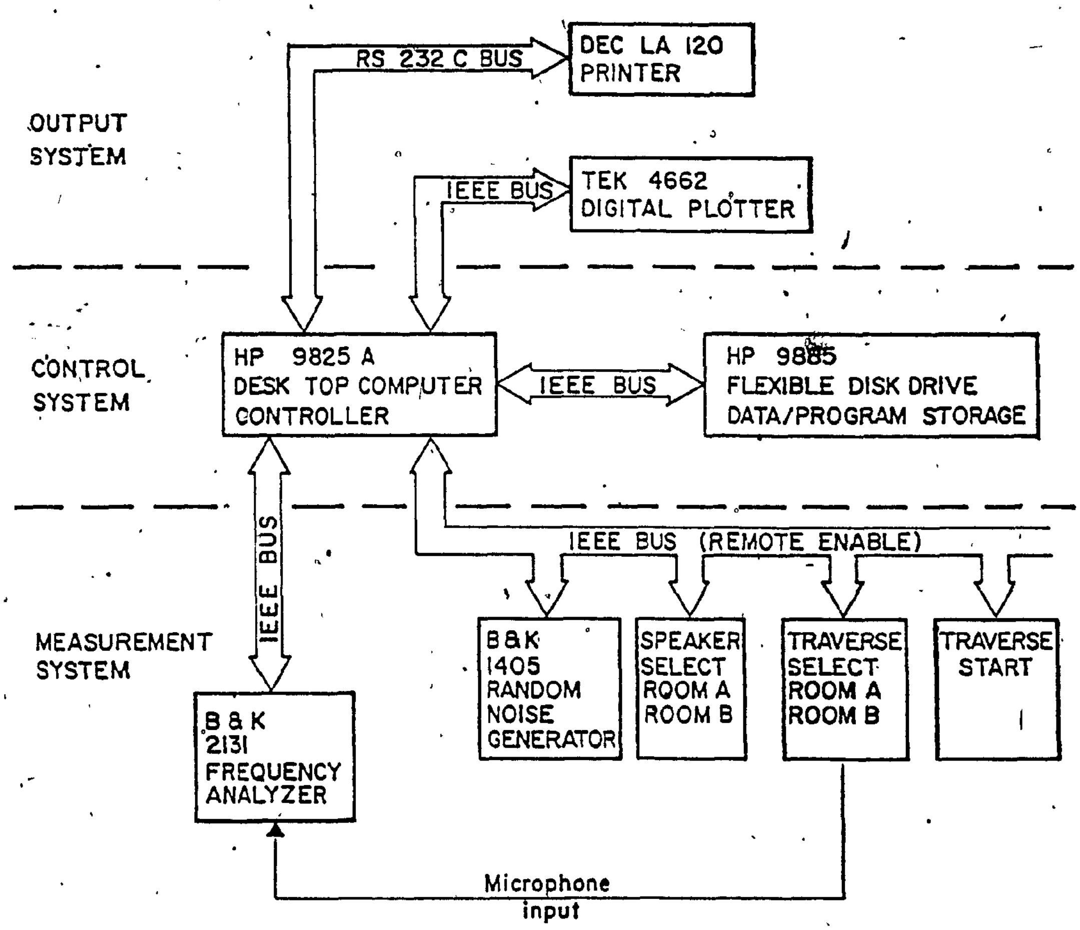


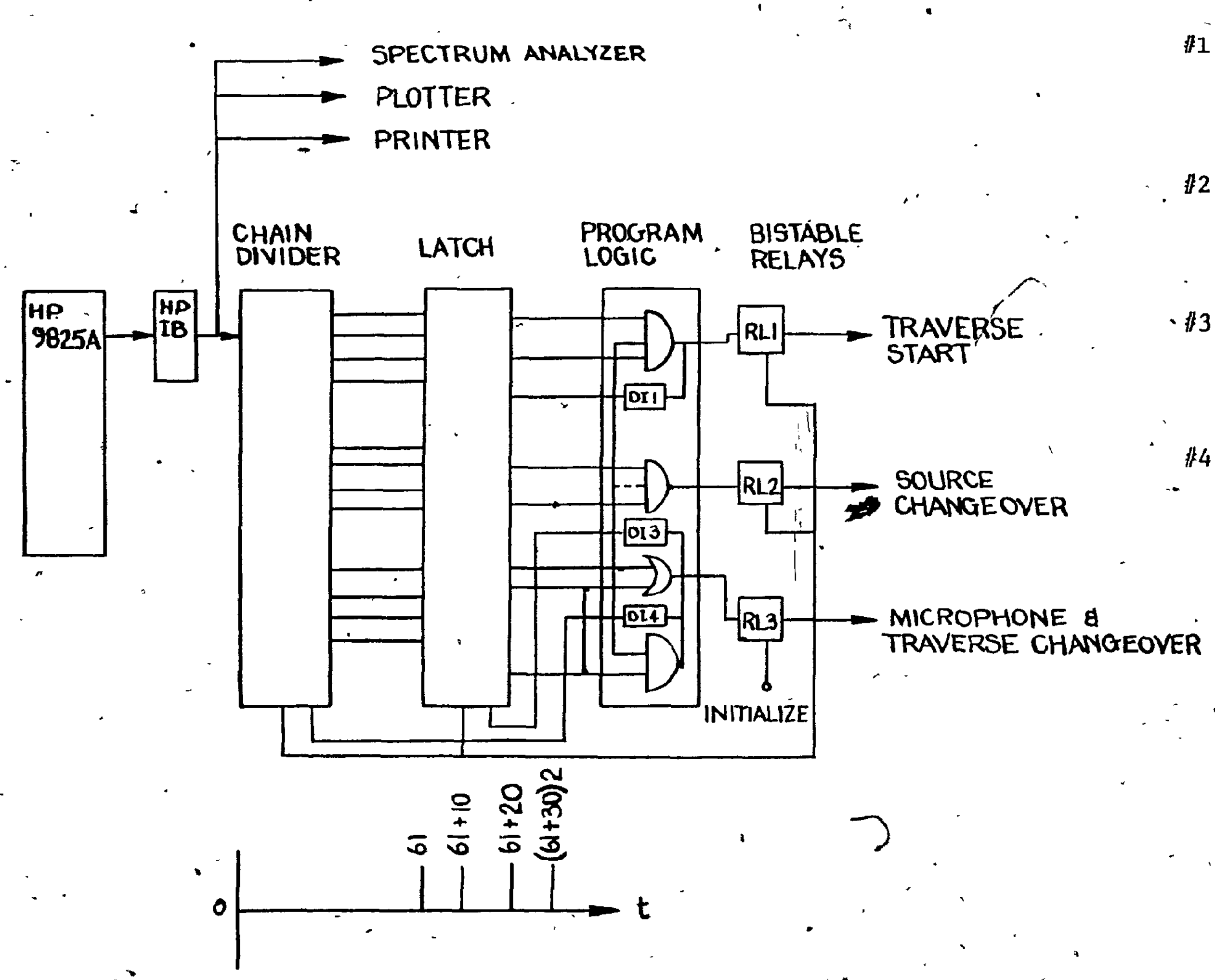
FIG. 2.4 Instrumentation set-up: Measurement, Control and Output systems.

In each room pressure levels were sensed by a 12.7mm B & K 4133 microphone and B & K 2619 preamplifier moving on a three meter traverse along the main room diagonal, cabled to a B & K 2131 real time digital 1/3-octave frequency analyzer. The information was processed and displayed on the analyzer which is digitally controlled through the IEC interface by the HP 9825A desk-top computer. Signals were generated by a B & K 1405 random noise generator through B & K 2706 power amplifiers to loudspeakers.

The selection of the microphone traverse and loudspeaker as well as the noise generator and start time of the traverse were computer controlled. Fig. 2.5 is a block diagram of the mic/traverse and source control relays and logic. Sequences that were required to control the microphone and source location are shown in Fig. 2.5(b) (bottom) along with the four commands (top) in HP 9825A language that were set up for control purposes. The program that was written included all the sequences in a manner such that the proper sequence was selected depending on which room required the mic/traverse or source position.

The microphones were calibrated with a B & K 4220 pistonphone and, temperature and humidity were recorded for the rooms before and after each test.

Through a parallel interface of the HP 9825A with an HP 9885M flexible disk drive data storage and software programs were implemented. Data output can be on a Tektronix 4662 digital plotter on the IEC interface or on a Digital Equipment LA 120 printer.



(a)

#1
```
forJ=1to61;lcl7;
wait.01;rem7;nex
tJ
```

#2
```
forJ=1to71;lcl7;
wait.01;rem7;nex
tJ;beep
```

#3
```
forJ=1to81;lcl7;
wait.01;rem7;nex
tJ;beep
```

#4
```
forJ=1to91;lcl7;
wait.01;rem7;nex
tJ;wait3000;beep

forJ=1to91;lcl7;
wait.01;rem7;nex
tJ;wait3000;beep
```

SEQUENCE:

1. Initial reset sets mic & traverse in room A.
2. #4 sets mic & traverse in room B.
3. #3 sets source in room B.
4. #2 sets source in room A.
5. #1 starts the traverse.

(b)

FIG. 2.5 Mic/Traverse and Source control

Control of the measurement system during data acquisition and storage and the output system was through programs developed for the HP 9825A. The two main programs for room reverberation time and panel transmission loss which will be discussed later are included in Appendix A. Programs were also written for the HP 9825A for data retrieval and calculation of panel transmission loss.

2.3 EXPERIMENTAL SET-UP

A summary of the characteristic configurations of the various panels used is presented in Table 2.1. Sill dimensions are also included in Table 2.2, but their effect on TL measurements is reported elsewhere(16).

TABLE 2.1 Panel Configurations

PANEL SIZE	PANEL MATERIAL	DIMENSIONS* m^2	THICKNESS* mm	OTHER
Size 1	Glass	0.54	6.350	–
	Single Gyp		15.875	–
	Double Gyp		47.625	including 15.875mm airspace between panels
Size 2	Glass	2.32	6.350	–
	Single Gyp		15.875	–
	Double Gyp		47.625	including 15.875mm airspace between panels
Size 3	Glass	3.93	6.350	–
	Single Gyp		15.875	–
	Double Gyp		47.625	including 15.875mm airspace between panels

* all values are nominal

Table 2.2 Sill Configurations*

Sill Size	MATERIAL	WIDTH m	THICKNESS mm
Size 1†	Plywood	0.305	6.35
Size 2	Plywood	0.153	6.35

* Sill length dependended on panel dimensions
† 0.153 & 0.153 plywoodstrips used for this size

The diffusing elements in the rooms as described earlier consist of a rotating vane and stationary diffusers of which two sets of panels are located in room A and four panels in room B. The arrangement of the stationary and rotating diffusers is illustrated in Fig. 2.6. The rotating diffuser consists of eight trapezoidal plywood panels coated with polyurethane to avoid high frequency absorption, and fastened to support rods connected to the central shaft[14]. The diffuser rotates with a speed of 30 rpm. The sandwich panels are made of a 50.8mm thick core sourrounded by 50.8 x 50.8mm pine. Aluminium sheets, 0.635mm thick, were glued to each panel face. The dimensions of the panels are 1.83 x 0.61 meters. Sets were made, for ease of placement, by connecting three panels together with aluminum I-beams.

The loudspeakers are situated at the corner of each room where the maximum possible room modes will be excited.

For each type of panel and panel size a series of tests was performed for each mounting orientation. Mounting orientation implies that the partition is mounted such that there is a niche on one room

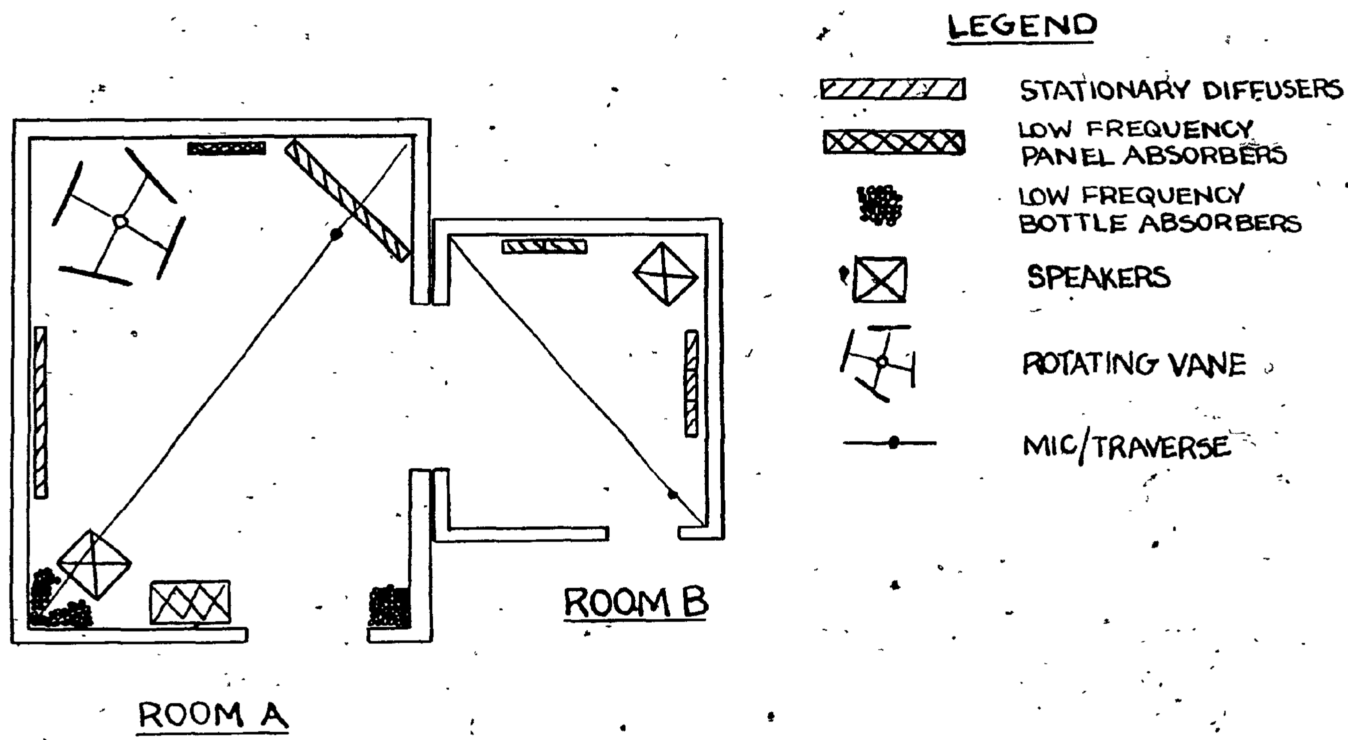


FIG. 2.6 Arrangement of diffusers, speakers and low frequency absorbers.

side only. Thus when speaking of "mounting orientation is in room A" it shall be understood that the niche is present on the side of room B only.

The tests were carried out according to the following set up:

a) The panel was mounted in the frame

and b) Two 0.153m plywood strips were attached together and mounted to form the size 1 sill effect.

With the above set-up two tests were performed, one with diffusers (diffusers on) and one without (diffusers off). For "diffusers on" the conditions were that stationary diffusers were angled and the rotating diffuser was on. "Diffusers off" had stationary diffusers on floor and rotating diffuser off. With these two testing configurations a comparison can be made on the effect of the amount of diffusing elements on the measured transmission loss. The same tests were repeated for the size 2 sill effect. Again, tests were repeated with no sill conditions. Thus six tests in all were carried out with and without sills. The next two tests, to complete the set, were carried out by exchanging receiving rooms and measuring SPL's with and without diffusers and with no sill conditions. Fig. 2.7 illustrates the experimental set up for the panels mounted in room A and in room B. A listing of the tests is presented in Appendix B. A total of 144 TL measurements were made.

2.4 MOUNTING

All panels were installed in a uniform fashion to avoid the effects of boundary conditions affecting results and in a manner as

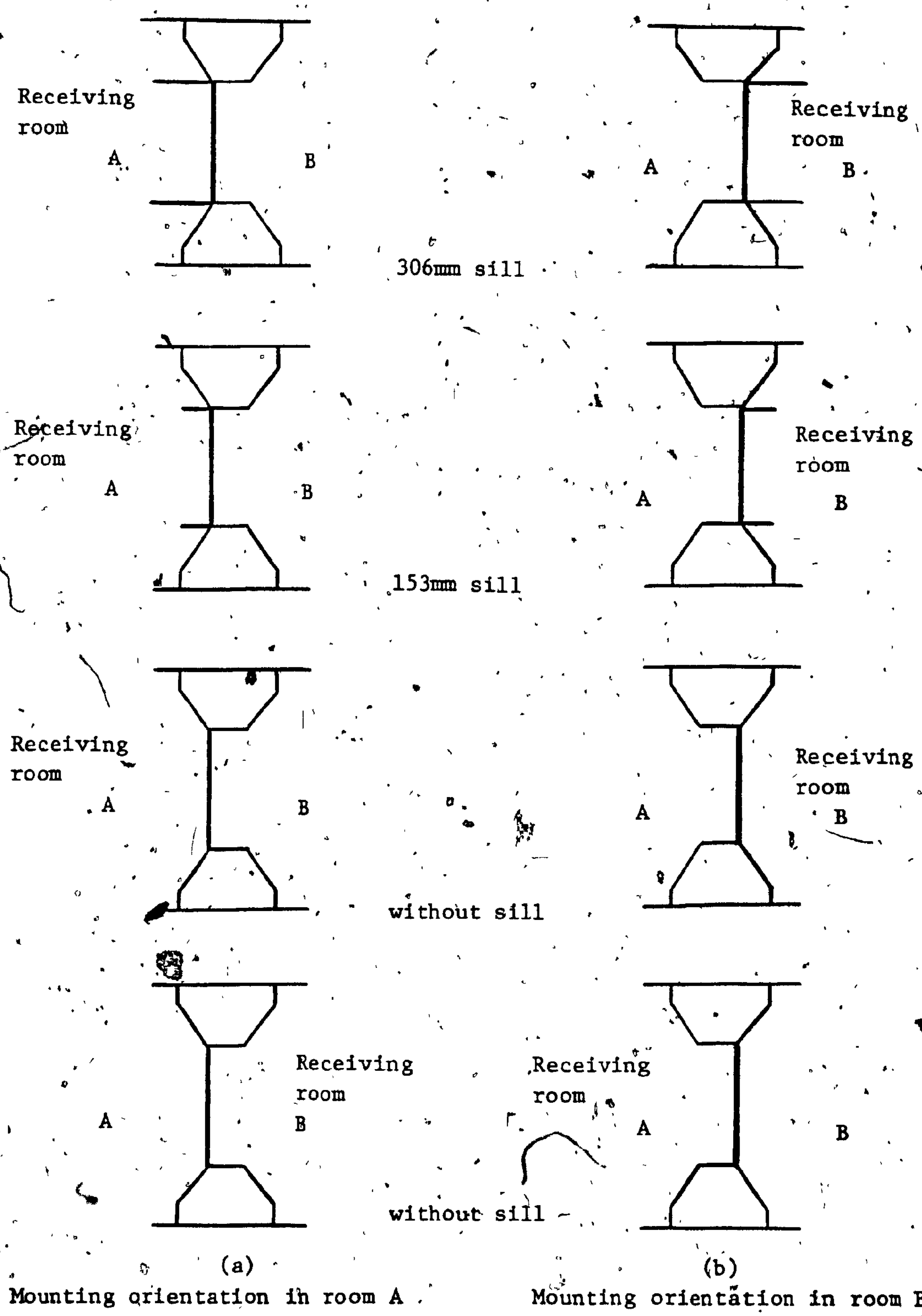


FIG. 2.7 Experimental set-up of panel mounting orientation.

similar as possible to actual construction methods. The mounting of the panels shown in Fig. 2.8 is as follows:

a) 4 angle bars were screwed on the sides of the aperture

b) Weather stripping 19.05mm wide was placed around the perimeter of the apperture over the angle bars and one 6.35 mm was placed perpendicular to it.

c) The panel was mounted in place with 19.05 mm weather stripping placed around its perimeter.

d) All edges were sealed with caulking compound.

e) 4 angle bars were placed against the panel and screwed on the sides of the apperture to complete the mounting.

f) Gyprock joints where larger panels were used were sealed and taped

The sill was screwed in place on the angle bars around the panel edges and its corners were sealed with putty.

2.5 ABSORPTION IN RECEIVING ROOM (REVERBERATION PROGRAM)

The reverberation program (Appendix A) was set up to measure the rate of decay of sound and thus calculate the amount of absorption present in the receiving room for each test condition. Measurements were made in one third octave bands with centre frequencies from 100 to 5000 Hz.

Measurements of the decay rate were taken for each frequency band to satisfy the precision requirements as set up by ASTM C 423 [15] - which specifies 95% confidence in uncertainties of measured values of absorption. The percent of uncertainty for the two frequency ranges as specified is shown in Table 2.3.

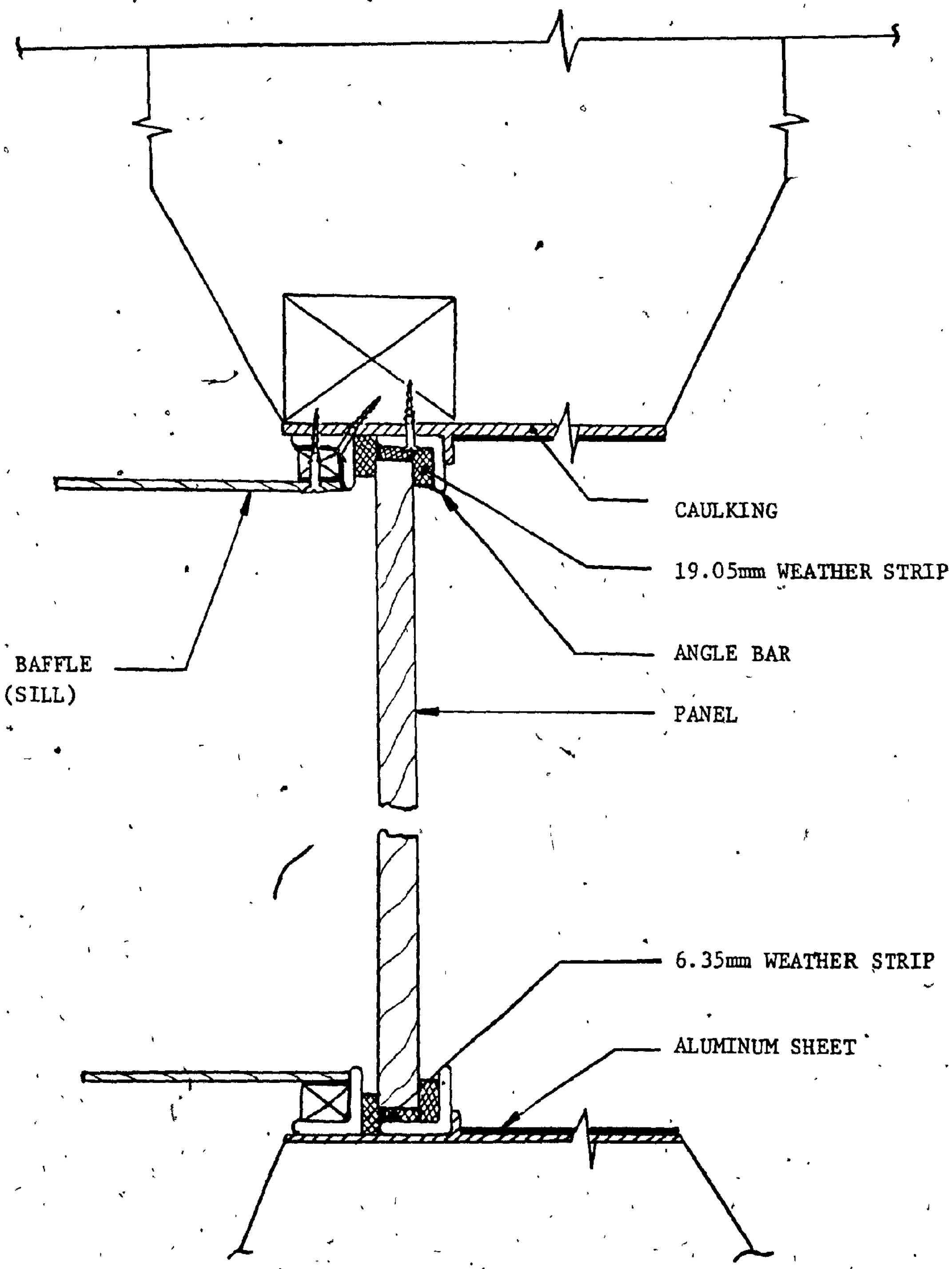


FIG. 2,8 Method of installation of panels and sills.

1/3 Octave Centre Frequency (Hz)	Uncertainty %
Below 250	less than 4
250 and above	less than 2

TABLE 2.3 Uncertainty range for measured values of absorption

For each band the standard deviation is calculated from

$$SD = (n-1)^{-\frac{1}{2}} \left[\sum_{j=1}^{n} (d_j - \bar{d})^2 \right]^{\frac{1}{2}} \tag{2.1}$$

where SD = standard deviation , dB

d_j = individual measurement, dB

$$\bar{d} = \frac{1}{n} \sum_{j=1}^{n} d_j = \text{average value of n measurements, dB}$$

from which the confidence limits are found from the following expression:

$$\bar{d} \pm a * SD \tag{2.2}$$

where $a = 1.96 * n^{-\frac{1}{2}}$ = Students t-distribution for observations greater than 25(15)

Fifty rate of decay measurements were taken for each 1/3-octave frequency band. The microphone was positioned at the top end of the traverse and the noise source was turned on long enough for the sound pressure level in the room to reach a steady state ($\sim$ 3 sec). The signal was then turned off and the decay rate measured, starting at a sound pressure level 5 dB below the level with the sound source on, either for a 30 dB decay or to a point 10 dB above the background level, whichever occured first. The average decay rate for the 50 decays was then calculated. The absorption of the room was found from

$$A_r = 0.921 \ V \, d/c \tag{2.3.}$$

where A_r = sound absorption in the receiving room, metric sabins

V = room volume, m^3

c = speed of sound, m/s

d = R/T_d = rate of decay, dB/s

where R = range of decay measured, dB

T_d = average time for the decay range, s

The average absorption values were then used in the transmission loss calculations.

2.6 SOUND TRANSMISSION LOSS OF THE TEST PANEL (TL PROGRAM)

The noise reduction (NR) in 1/3 octave bands, ie., the difference between the space-time average sound pressure levels in the source room and the receiving room, was measured. The term 'space-time average' indicates that a microphone sampled the reverberant field, moving along a 3-meter traverse in an average time of 32 seconds, to permit an accurate estimate of the time-average sound pressure level in each room.

Prior to sound pressure level measurements, the background level in the receiving room had to be determined to ensure that readings were not affected by instrument, electrical or other extraneous noises. Where the background level was found to be within 10 dB of the total level due to signal and background then corrections had to be made on the receiving room sound pressue levels. The equation for correction is a simple subtraction of decibel levels given as:

$$L_{cr} = 10 \log (10^{L_R/10} - 10^{L_B/10}) \quad (2.4)$$

where L_{cr} = corrected sound pressure level for background dB

L_R = Sound pressure level in the receiving room due to background and signal, dB

L_B = sound pressure level in the receiving room due to background, dB

Measurements where the background level was within 5 dB of the total level were treated as invalid.

As in the decay rate measurements, a sufficient number of measurements of the NR is required to meet the 95% confidence limits on the TL. The limits are presented in Table 2.4. Calculation of the standard deviation and the confidence limits are performed in a similar manner to that presented in Section 2.5 through use of Eqs. 2.1 and 2.2 where d is substituted for p since pressure levels were measured.

1/3 Octave Centre Freq. (Hz)	Maximum Acceptable Deviation (dB)
125 and 160	+ 3
200 and 250	+ 2
315 to 4000	+ 1

Table 2.4 95% Confidence Limits on Transmission loss measurements

Thirty (30) sound pressure readings for each room measured were made in each frequency band. For each test the microphone completes its sampling by moving along a 3 meter traverse for 32 seconds. The space time average sound pressure measured in each room is then converted into a pressure level by applying the decibel scale:

$$SPL = 20 \log (p/p_o) \quad dB \qquad (2.5)$$

where p is the space - time average sound pressure, μPa

p_o is the reference pressure = 20 μPa

The SPL in the receiving room is compared to the background level to assure that the difference between levels is greater than 10 dB otherwise the correction must be applied through Eq. 2.4. Finally, knowing the absorption in the receiving room, A_r, the panel surface area, S, and the noise reduction, NR, the transmission loss is calculated for the panel in question by use of Eq. 1.2. which states that the $TL = NR + 10 \log (S/A_r)$.

The test results along with an analysis and discussion are presented in the following chapters.

2.7 POSSIBLE SOURCES OF MEASUREMENT ERROR

Errors in measured SPL values could have resulted from improper sealing of panel perimeter (notably for frequencies above 4000 Hz where the TL curve decreases sharply), from improper sealing where panels were joined, or from noise generated by the mic/traverse mechanism at at the end of each microphone 3 meter traverse. If the microphone completed its 3 meter traverse before the 32 second averaging on the SPL then the analyzer processed the noise of the mechanism as well.

CHAPTER III

ANALYSIS OF TEST RESULTS

3.1 INTRODUCTION

When the transmission loss of each element of a typical construction is known then the overal transmission loss of a composite section can be calculated by summing the area weighted energies transmitted through each section. Since by definition $TL = 10 \log(\frac{1}{\tau})$ where τ (the transmission coefficient) is the fraction of randomly incident acoustic intensity that is transmitted by a given element, then

$$\tau_c S_c = \Sigma \tau_i S_i \tag{3.1}$$

where τ_c = transmission coefficient of the composite structure

S_c = total surface area of composite structure

τ_i = transmission coefficient of the ith section

S_i = surface area of ith section

The transmission loss of the reference wall and the composite wall were measured. The transmission loss of the panel alone was found by use of Eq. 3.1, through

$$TL_p = 10\log\left[\frac{1}{\frac{S_c}{S_p}10^{-TL_c/10} - \frac{S_R}{S_p}10^{-TL_R/10}}\right] \tag{3.2}$$

where TL_p = TL of panel, dB

TL_c = TL of composite wall, dB

TL_R = TL of reference wall, dB

S_c = surface area of composite wall, m^2

S_p = surface area of panel, m^2

S_R = $S_c - S_p$ = Surface area of composite wall less surface area of panel, m^2

Of the 144 transmission loss tests conducted in the transmission suite at CBS during this investigation only 72 cases will be reported here. Data when sills were introduced as a parameter affecting the transmission loss of a wall are discussed in Reference (16). The chart in Fig. 3.1 indicates the types of tests performed on the three materials. Results obtained for the reference wall are available in Appendix C.

From Eq. 1.8, the Schroeder Cut-off Frequency

$$f_{c,s} = 1200 \left(M \frac{T_{60}}{V}\right)^{\frac{1}{2}} \tag{1.8}$$

is calculated for room A in the 250 Hz Band, where the modal overlap is given the value 3 and the reverberation time is averaged at 1.5 seconds. Room B is found to have its room cut-off at about 400 Hz.

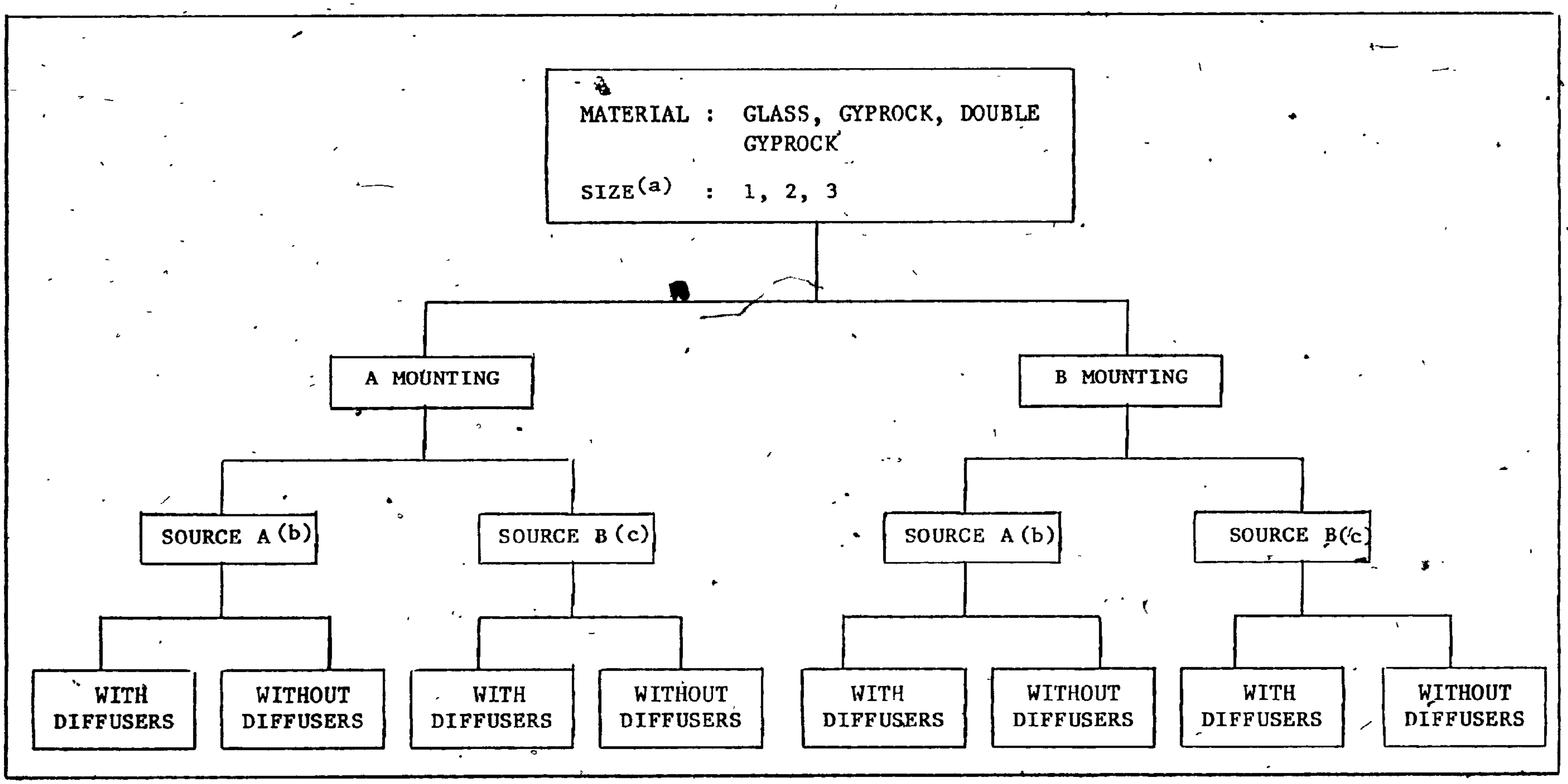
The coincidence frequency of the three panel materials can be calculated from[17]:

$$f_c = \frac{c^2}{2\pi} \sqrt{\rho_s / B} \tag{3.3}$$

where ρ_s = mass of the material, Kg/m^2

B = $Eh^3/12$ = the bending stiffness per unit width of the panel, N-m which has a value for glass of 704 N-m and 737 N-m for gyprock for panel thicknesses used in this study.

Properties of the materials are given in Table 3.1.



(a) Size 1 corresponds to nominal size of 0.54 sq meter
Size 2 corresponds to nominal size of 2.32 sq meters
Size 3 corresponds to nominal size of 3.93 sq meters
(b) Room A has nominal volume of 94.02 m^3
(c) Room B has nominal volume of 37.03 m^3

FIG. 3.1 TL tests on glass, gyprock & double gyprock panels varying the parameters (panel size, mounting, source room & diffusers)

TABLE 3.1 Material Properties

Material	(1) E x 10^{10} N/m^2	(2) ρ_m Kg/m^3	(3) h x 10^{-2} m	(4) T °C	(5) c m/s	(6) ρ_s Kg/m^2	(7) f_c, Hz (Eq. 3.4)
Glass	3.3	2500	.635	21.1	344.5	16.1	2856
Gyprock	0.22	650	1.59	21.1	344.5	12.68	2483
Air		1.21		21.1	344.5		

(1) Youngs Modulus of the panel material
(2) Density of the material
(3) Thickness of the material
(4) Average Room temperature
(5) Speed of sound in air
(6) Mass of material
(7) Critical frequency of the material

The effects on the measured transmission loss when the room parameters are varied will be discussed in the following sections where the transmission loss results are divided into three frequency regions for ease of analysis. These three regions are: the frequency range above coincidence (or critical frequency), between coincidence and room cut-off, and the range below the room cut-off. The frequency range of interest which shall be dealt with here includes frequencies from 125 Hz to 5000 Hz. Even though readings at 100 Hz were measured and are included in the figures, the analysis excludes them as being out of the range of interest of this study.

3.2 VARYING PANEL AREA

Table 3.2 is a tabular summary of the TL tests for each panel material as a function of the varying panel areas and constant room parameters. When impossible to represent a particular spectrum characteristic through the table, figures will be referred to. For instance, Table 3.2 (a) does not indicate that between 1600 Hz and 2500 Hz the measured transmission loss of panel size 1 is higher than that of panel size 3. Fig. 3.2 however, clearly shows the differences.

3.2.1 Double Gyprock Panels

The measured coincidence (critical frequency) for the double gyprock panels occurs at 2500 Hz as was calculated. When the critical frequencies of single panels are identical, then incident sound waves and panel bending waves reinforce each other, which results in a large dip in the transmission loss curve, ie. the transmission of sound increases. Fig. 3.2 shows that panel size 3 has a large dip whereas that of panel size 2 is shallow and panel size 1 exhibits a somewhat broad, shallow dip. Such results can be attributed in the case of panel size 1, to the small area that is tested where the entrapped air can behave as a stiffness element increasing the transmission loss. Other parameters that can have an effect on the length of the dip shall be discussed later.

According to References (10) and (18) the TL of a wall increases with increasing radiation area below coincidence. In Table 3.2 the results indicate that this is not always true for the double gyprock panels. In two cases, (a) and (b), panel 3 has the highest TL but in the other two, (c) and (d), it has the lowest TL. Usually panel size 2 has the lowest measured TL. This variation is possible due to panel construction since panel 1 was a single piece of gyprock cut from a larger panel whereas due to their sizes, panels 2 and 3 were sized and cut from two gyprock panels and joined as discussed in Chapter II. Because panel size 3 was made up of two equal panels it most likely responded more as a single panel than did panel size 2 which was made up of two unequal panels.

In the double gyprock construction of panel size 2 it was not noted whether the joint of the first panel coin ided with the joint of the second panel. If the joints coincided then the panels would most likely vibrate as one whereas if they did not coin ide then each panel would vibrate independently increasing the measured TL. Thus it is not possible to determine whether some room parameter or the panel configuration is creating the variations mentioned above.

Below the room cut-off frequency, panel size 1 dips at the 160 Hz and 250 Hz bands which indicates resonance. Before the second dip occurs the TL of this panel usually increases well above the TL of panel sizes 2 and 3 as shown in Fig. 3.2.

3.2.2. Gyprock Panels

The critical frequency of gyprock panels is calculated to be 2500 Hz. Comparing Figs. 3.3, 3.4, 3.5 and 3.6 it is found that the critical frequency for the same material varies. The critical frequency of a partition depends on its mass and stiffness. Noting the differing coincidence dip measured it could be said that the Youngs modulus for the material varied for the panels tested. But as the panels were all from similar gypsum board the Youngs modulus should have been the same and since for one of the configurations all panels had the critical frequency occuring at 2500 Hz then some room parameter seems to be affecting the frequency where theoretically coincidence should occur.

From Table 3.2 it is clear that panel size 1 has the highest TL above the cut-off frequency and the lowest TL below the cut-off. Panel sizes 2 and 3 usually have a similar TL. Again the results are not in agreement with theory as was the case for the double gyprock panels.

A comparison of the measured transmission loss with the mass law theory, Fig. 3.7, shows that there are differences between the curves particularly at the lower frequencies where the curves lie above the mass law. Because adequate instruments were not available to measure the mass of the test panels the value of m was assumed in the calculation of the mass law. Thus, even though experimental and theoretical values tend to agree, the fact still remains that the mass law curve might have either an upward or a downward shift depending on the actual value of m. If the mass of the panel is higher than that assumed then the measured TL of the panels will be in better agreement with the mass law at the lower frequencies.

3.2.3 Glass Panels

From Eq. 3.4, the critical frequency of glass was calculated to be 2800 Hz. This indicates, when considering 1/3 octave bandwidths, that the measured critical frequency will occur either in the 2500 Hz or 3150 Hz band. Fig. 3.8 shows that panel size 1 dips at 3150 Hz whereas the critical frequencies of panel sizes 2 and 3 occur at 2500 Hz. Similar results are obtained when mounting orientation, diffusing conditions and room dimensions are varied.

Above the cut-off frequency, panel size 1 usually has the highest TL whereas size 2 has the lowest TL. Below the cut-off size 1 has the lowest TL, whereas size 3 has the highest TL. In Fig. 3.9 the mass law curve is compared to the measured TL and depicts a similar pattern at the lower frequencies as that obtained for the gyprock panels. Here only panel size 1 is in closer agreement with the mass law theory.

3.2.4 PANEL AREA VARIATION AND ITS EFFECT ON TL

From the previous sections, in reference to the graphs and table, it is evident that when the panel area of a specific material is varied, the TL either increases or decreases depending on the particular parameters of a specific case. It should also be noted that when the panel area is varied there seems to be a change in the measured critical frequency of some of the panel materials under test. The value of the critical frequency decreases when panel thickness and material stiffness is increased, and increases with increasing material density[19] but should not be dependent on panel area. The glass panels considered, as well as the gyprock panels, which show an increase in f_c from that of calculated values, have non-varying material properties, except for change in the panel area, thus the coincidence frequency should not have been affected and it will be seen later that this change is a function of mounting position.

3.3 VARYING ROOM VOLUME

Tables 3.3 and 3.4 present in tabular form the TL of each panel material tested as a function of varying room dimensions with constant room parameters. Table 3.3 represents results when mounting orientation is in room B and Table 3.4 when mounting orientation is in room A.

3.3.1 Double Gyprock Panels

Above the critical frequency the TL is generally similar whether A or B act as receiving rooms which is in agreement with theory. Below the room cut-off the TL is lower when A is receiving and this can be directly attributed to the small volume of room B and its fewer characteristic frequencies. At low frequencies the chances that the sound pressure level will be made up of simultaneously excited vibrational modes is less, since there are fewer modes whose distribution in frequency space is not uniform. Thus transmission through the panel due to resonance will be higher.

Between the cut-off frequency and coincidence dip it is noted that the TL is slightly higher when B is the receiving room and mounting orientation of the panels is in room A. Thus the TL is not only dependent on volume in this frequency region, but to mounting orientation as well. At 1600 Hz (refer to Fig. 3.2) the curve of panel size 1 always peaks above the other curves when room B is receiving. The difference between curves is usually anywhere from 4 dB to 12 dB. A probable and most likely explanation of this increase in TL in the 1600 Hz band is that the sound pressure level in the receiving room (due to source plus background) was within 1 to 5 dB of the background level alone. This resulted in a higher NR thus a peak in the TL curve at that frequency band. This problem was encountered in the earlier experiments for the double gyprock panels when partition size 1 was tested, and corrections were made on subsequent testing.

3.3.2 Gyprock Panels

The TL results of gyprock panels, when comparing variation of room dimensions, are of a similar nature to results of double gyprock panels.

3.3.3 Glass Panels

From the tables the TL results of glass panels are again noted to be similar to those of double and single gyprock panels.

3.3.4 ROOM VOLUME AND ITS EFFECT ON THE MEASURED TL

When receiving room dimensions are varied the results generally indicate that in the frequency range between room cut-off and 5000 Hz the TL is slightly higher when the receiving room has small dimensions, ie. when B is the receiving room. Above the coincidence dip the TL is usually similar whether A or B act as receiving rooms but below the cut-off frequency the TL is higher when B is receiving.

The number of modes present in a room is directly dependent on the volume of the room. To achieve an adequate number of room modes the minimum room volume should be $4\lambda^3$ for a band centred on the lowest frequency of interest and as was previously discussed, volumes down to $2\lambda^3$ are acceptable . As well as meeting the above requirement, room A has low frequency absorptive treatment to further broaden the modal response, and a rotating vane to increase diffusion. The reverberation time is higher than that measured in room B and the sound pressure levels observed throughout the room have spatial variations within ± 1 dB

To calculate the TL three measurements are required. The first is the absorption in the receiving room and the second is the SPL in the receiving room. The last measurement needed is the SPL in the source room . TL is dependent on the absorption and on the SPL in the receiving room, and to obtain reliable data the characteristics of the receiving room should be those defined above. Thus measurements made when room A is the receiving room will be statistically more reliable whereas those made when room B is the receiving room should be approached with care.

3.4 DIFFUSING CONDITIONS

Tables 3.5 through 3.8 represent the TL of each panel material tested as a function of the amount of diffusion present in the room when the other room parameters are kept constant.

3.4.1 Double Gyprock Panels

Results are similar with and without diffusers as indicated in Tables 3.5 to 3.8. From Figs. 3.10 and 3.11 slight differences are noted below the room cut-off. An explanation of how the diffusing conditions in the room were achieved is given in Section 2.3. Since room B had only stationary diffusers then its diffusing conditions were either diffusers on or diffusers off. This however, was not the case for room A which had a rotating diffuser. When it was turned off it still acted as a diffuser - a stationary diffuser - since it was not possible to remove it from the room. The differences therefore between room A and room B should occur at the lower frequencies where the modal density is higher for room A than B.

The results obtained agree with theory, in that at the higher frequencies there is a sufficient number of modes which are evenly spaced in frequency reducing to an acceptable minimum the spatial variations in the sound pressure level throughout the rooms. At the lower frequencies where additional diffusion is needed this does not occur. But it should be kept in mind that the differences in results occur below the cut-off frequency of the room where the reverberant sound field cannot be considered reliable for the room volumes considered herein, without the use of diffusing elements.

3.4.2 Gyprock Panels

As in the double gyprock panels where the TL is generally similar with and without diffusers, the single gyprock panels have TL results which are frequently in agreement with comments made in Section 3.4.1 regarding double gyprock panel results. Figs. 3.12 and 3.13 show the two TL curves and the differences that usually occur at the low frequencies. In Fig. 3.14 the measured TL is slightly higher, but with differences of not more than 2 dB when there are no diffusing elements in the rooms. This occurs only for the small size panel when mounting orientation is in room A and B is the receiving room.

3.4.3 Glass Panels

Here again, except for two parameter conditions, the remarks of double gyprock panels apply for glass panels as is evident from Tables 3.5 to 3.8 and Fig. 3.15.

The two parameter conditions where results differ are shown in Figs. 3.16 and 3.17, where the TL is higher when there are no diffusing elements in the rooms, as is the case for size 1 of the single gyprock panels. The maximum difference betweens curves is 4 dB for frequencies below the critical frequency.

3.4.4 Diffusing Conditions and Effects on Measured TL

When the panels are tested with diffusion present in both rooms and the measured results are compared for similar testing conditions without diffusion in the rooms, the differences in the TL is seen to be very slight for frequencies above the cut-off frequency for most panels, which tends to agree well with theoretical observations of room characteristics. Below the cut-off frequency the results are unstable, when room A is receiving no clear trends are evident, while when room B is receiving the measured TL is higher when the diffusing elements are present especially evident when mounting orientation is in room A.

3.5 MOUNTING ORIENTATION OF PANELS

Tables 3.9 and 3.10 represent the TL of each panel material tested as a function of the two mounting orientations with remaining room parameters kept constant.

3.5.1 Double Gyprock Panels.

The results obtained when comparing the same panel area but varying the mounting orientation, indicate that mounting orientation has an effect on the measured TL. Whereas in most results obtained the measured TL when mounting is in room A is similar to that when mounting is in room B, Figs. 3.18 and 3.19 demonstrate the large differences that occur at the mid frequencies (below coincidence). Panel size 3 has a higher TL when mounting orientation is in room A, from Fig. 3.18, and panel size 2, shown in

Fig. 3.19 has a much higher TL when mounting orientation is in room B. As well, the panel displays a large dip when mounted in B compared to a very shallow dip when mounted in A, as discussed in Section 3.2.1

3.5.2 Gyprock Panels

The only large differences between the two curves as shown in Fig. 3.20 occurs at the critical frequency of the gyprock panel. When mounting orientation is in room A the coincidence dip is deeper by as much as 7 dB than that of the shallow dip measured when mounting orientation is in room B. Panel sizes 1 and 2 seem to be affected by mounting position at their critical frequencies in that the dips occur at different frequencies depending on mounting orientation.

For panel size 1 when mounting orientation is in room A the dip occurs at 3150 Hz and when mounting orientation is in room B the dip occurs at 2500 Hz. The opposite is true for panel size 2, none the less it appears to be a characteristic of the mounting orientation.

3.5.3 Glass Panels

The glass panels tested here are not significantly affected by mounting orientation, for frequencies between room cut-off and coincidence, with only panel size 3 displaying a slightly higher TL when the panel is oriented in room B. At frequencies above coincidence the TL is slightly higher when mounting orientation is in room B as shown in Figure 3.21. Below the room cut-off the panels generally display results (Table 3.9 and 3.10) where size 3 has slightly higher TL values when mounting is in room B. Sizes 1 and 2 display slightly higher TL values when mounting orientation is in room A and when B is the receiving room.

3.5.4 PANEL ORIENTATION AND ITS EFFECT ON THE MEASURED TL

Large differences in transmission loss between mounting orientations were noted particularly in the two larger double gyprock panel sizes. Smaller differences are seen for single gyprock panels. These results do not agree with Gosele[20] where it is found that a niche on the transmitting side decreases the transmission loss. But the results do agree with those found by Kihlman and Nilsson[3] where a niche on the receiving room side gives higher transmission loss values. Thus, as is generally found to happen in these tests, when A is the receiving room and when the panel mounting orientation is in room B, the measured transmission loss is slightly higher than when the panel mounting orientation is in room A.

Another effect, shown for the gyprock panels size 1 and 2, is the shift in the measured coincidence frequency as a result of mounting orientation.

3.6 DISCUSSION

From the experimental results the TL of the panels is found to not only depend on material properties and edge conditions of the panel but as well on panel size and room parameters. The most significant effects are noticed when the panel surface area is varied, and when the mounting orientation and source room dimensions are changed. Diffusing conditions create variations in the TL of panels usually at the low frequencies but have little effect at frequencies above the room cut-off, which is to be expected since diffusion is mostly required at the low frequencies where fewer modes exist.

Most of the differences in TL results noted for the test panels occur at and above coincidence and at the low frequencies, below room cut-off, with the exception of changing panel dimensions which also affected the mid frequency region.

A major result of varying parameters that affect the transmission loss is noted for glass and single gyprock panels where mounting orientation and panel size increase the measured critical frequency of the materials. If the loss factor for the panel is known, (determined through reverberation measurements) the predicted transmission loss of the panels can be calculated from[19]

$$TL = TL_o + 10 \log (2\eta f/\pi f_c) \quad \text{for } f>f_c \tag{3.4}$$

where $TL_o = 20 \log (\omega\rho_s/2\rho c)$ = TL for sound waves incident normal to the panel

η = loss factor of the panel

f_c = calculated critical frequency, Hz

f = frequency of interest, Hz

ω = angular frequency = $2\pi f$, Hz

ρ_s = mass of the panel, kg/m^2

as a check on agreement between theoretical and measured transmission loss results for frequencies greater than the critical frequency. Since the panel loss factor was not obtained, its value was assumed from tables on material properties[19, 17] and the necessary calculations made indicated that the measured results agreed quite well with theory for frequencies above the critical frequency of the material.

The panel loss factors that were used in the calculations of the mass law were 0.012 for gyprock[19] and 0.006 for glass[17].

Comparison between results obtained in this facility and other test facilities indicate the following trends:

1) A nich can affect the measured TL of a wall especially for frequencies below coincidence, as reported by Kihlman & Nilsson[3] in the TL results obtained at five participating laboratories. As well, Gösele[20] and others[23] report a definite effect on the measured TL when a nich is present.
2) The measured TL is generally larger than that predicted by the mass law as reported by Kihlman & Nilsson[3] and Utley[22]. The results obtained here agree with the above statement.
3) Above coincidence the TL is independent of panel dimensions but for low frequencies the TL decreases with increasing area and for high frequencies it increases with increasing area. Such results are found to be in accordance with those in the literature

except for varying opinion concerning the forced transmission[10,12,18]. In (10) the forced transmission is assumed independent of panel area whereas Sewell[12] reports the opposite. In this study it was found that the forced vibration dominated for low frequencies thus the TL decreased with increasing panel area at low frequencies.

4) For frequencies above coincidence results indicate good agreement between labs and room geometry is found not to affect the TL, whereas below coincidence the variations are larger - in agreement with theory.

3.7 SYMBOLS USED IN THE TABLES

I	:	Above coincidence frequency
II	:	Between coincidence and cut-off frequency
III	:	Below cut-off frequency
a	:	Less than 1.5dB difference between TL curves (similar TL)
b	:	1.5 to 3dB difference between TL curves (slightly higher TL)
c	:	3 to 5dB difference between TL curves (higher TL)
d	:	More than 5dB difference between TL curves (much higher TL)
√	:	Indicates for which parameter the TL is highest, and the difference (b, c, or d) between the higher TL and lower TL.
X	:	Indicates for which parameter the TL is lowest, and the difference (b, c, or d) between the lowest TL and next highest TL
S	:	Indicates similar TL
$S_{\checkmark}$	:	Indicates similar TL between two curves but higher TL than the third curve
S_X	:	Indicates similar TL between two curves but lower TL than the third curve

MATERIAL	a			SIZE 1									SIZE 2									SIZE 3									* REFERENCE FIG. NO.
	I	II	III	I			II			III			I			II			III			I			II			III			
				b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	
	(a) MOUNTING ORIENTATION A - SOURCE A																														
DOUBLE GYP.			S_x*										x					x						✓			✓*		✓		3.2
GYPROCK	S_x	S_x				✓	✓			x																		✓			
GLASS	S_x					✓		✓		x							x											✓			
	(b) MOUNTING ORIENTATION A - SOURCE B																														
DOUBLE GYP.											x			x				x						✓			✓*			✓	3.3
GYPROCK	S_x	S_x		✓			✓			x									✓												
GLASS					✓				✓	x				x		x													✓		
	(c) MOUNTING ORIENTATION B - SOURCE A																														
DOUBLE GYP.	S_x	S✓									x												✓			x			✓		
GYPROCK		S	S✓	✓							x		x																✓		
GLASS	S_x			✓							x		x													✓				✓	
	(d) MOUNTING ORIENTATION B - SOURCE B																														
DOUBLE GYP.		S✓	S✓								x		x										✓			x					
GYPROCK			S✓		✓			✓		x				x		x															
GLASS		S✓			✓						x		x				x												✓		

Refer Section 3.7 for symbols

TABLE 3.2 Varying panel sizes

MATERIAL	MOUNTING ORIENTATION B																				
	a			SOURCE ROOM B									SOURCE ROOM A								
	I	II	III	I			II			III			I			II			III		
				b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d
DOUBLE GYP SIZE 1	S	S																		✓	
DOUBLE GYP SIZE 2	S															✓			✓		
DOUBLE GYP SIZE 3	S	S																	✓		
GYPROCK SIZE 1	S	S																	✓		
GYPROCK SIZE 2													✓			✓			✓		
GYPROCK SIZE 3	S	S																	✓		
GLASS SIZE 1	S	S	S																		
GLASS SIZE 2	S															✓			✓		
GLASS SIZE 3	S															✓				✓	

Refer Section 3.7 for symbols

TABLE 3.3 Varying source rooms: mounting orientation in B.

MATERIAL	MOUNTING ORIENTATION A																				
	a			SOURCE ROOM B									SOURCE ROOM A								
	I	II	III	I			II			III			I			II			III		
				b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d
DOUBLE GYP SIZE 1													✓			✓				✓	
DOUBLE GYP SIZE 2	S															✓			✓		
DOUBLE GYP SIZE 3	S															✓			✓		
GYPROCK SIZE 1															✓	✓				✓	
GYPROCK SIZE 2	S															✓			✓		
GYPROCK SIZE 3	S															✓				✓	
GLASS SIZE 1	S	S																		✓	
GLASS SIZE 2	S															✓				✓	
GLASS SIZE 3	S															✓				✓	

Refer Section 3.7 for symbols

TABLE 3.4 Varying source rooms: mounting orientation in A.

MATERIAL	MOUNTING ORIENTATION B - SOURCE B																					* REFERENCE FIG. NO.
	a			WITH DIFFUSERS									WITHOUT DIFFUSERS									
	I	II	III	I			II			III			I			II			III			
				b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	
DOUBLE GYP SIZE 1		S	S										✓									
DOUBLE GYP SIZE 2	S	S								*✓												3.7
DOUBLE GYP SIZE 3	S	S																	*✓			3.8
GYPROCK SIZE 1	S	S	S																			
GYPROCK SIZE 2	S	S								*✓												3.9
GYPROCK SIZE 3	S	S								*✓												Similar to 3.9
GLASS SIZE 1	S	S								✓												
GLASS SIZE 2	S	S								*✓												Similar to 3.12
GLASS SIZE 3	S	S								*✓												3.12

Refer Section 3.7 for symbols

TABLE 3.5 Varying diffusing conditions: mounting orientation in B, source in B.

MATERIAL	MOUNTING ORIENTATION B - SOURCE A																					* REFERENCE FIG. NO.
	a			WITH DIFFUSERS									WITHOUT DIFFUSERS									
	I	II	III	I			II			III			I			II			III			
				b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	
DOUBLE GYP SIZE 1	S	S									✓											
DOUBLE GYP SIZE 2	S	S																	✓			
DOUBLE GYP SIZE 3	S	S								✓												
GYPROCK SIZE 1	S	S									* ✓											3.10
GYPROCK SIZE 2	S	S									✓											
GYPROCK SIZE 3	S	S									✓											
GLASS SIZE 1	S															✓				✓		
GLASS SIZE 2	S	S								✓												
GLASS SIZE 3	S	S								✓												

Refer Section 3.7 for symbols

TABLE 3.6 Varying diffusing conditions: mounting orientation in B, source in A.

MATERIAL	MOUNTING ORIENTATION A - SOURCE B																					* REFERENCE FIG. NO.
	a			WITH DIFFUSERS									WITHOUT DIFFUSERS									
	I	II	III	I			II			III			I			II			III			
				b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	
DOUBLE GYP SIZE 1		S	S		✓																	
DOUBLE GYP SIZE 2	S	S	S																			
DOUBLE GYP SIZE 3		S		✓															✓			
GYPROCK SIZE 1														✓		✓			✓			
GYPROCK SIZE 2	S	S																	✓			
GYPROCK SIZE 3	S	S																	✓			
GLASS SIZE 1	S	S	S																			
GLASS SIZE 2	S																* ✓			* ✓		3.14
GLASS SIZE 3	S	S																	✓			

Refer Section 3.7 for symbols

TABLE 3.7 Varying diffusing conditions: mounting orientation in A, source B.

MATERIAL	MOUNTING ORIENTATION A - SOURCE A																					* REFERENCE FIG. NO.
	a			WITH DIFFUSERS									WITHOUT DIFFUSERS									
	I	II	III	I			II			III			I			II			III			
				b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	
DOUBLE GYP SIZE 1	S	S									✓											
DOUBLE GYP SIZE 2	S	S									✓											
DOUBLE GYP SIZE 3	S	S									✓											
GYPROCK SIZE 1													✓			✓			* ✓			3.11
GYPROCK SIZE 2	S	S									✓											
GYPROCK SIZE 3	S	S									✓											
GLASS SIZE 1	S	S									✓											
GLASS SIZE 2	S	S									✓											
GLASS SIZE 3	S	S									✓											

Refer Section 3.7 for symbols

TABLE 3.8 Varying diffusing conditions: mounting orientation in A, source A.

MATERIAL	SOURCE ROOM B																					* REFERENCE FIG. NO.
	a			MOUNTING ROOM B									MOUNTING ROOM A									
	I	II	III	I			II			III			I			II			III			
				b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	
DOUBLE GYP SIZE 1			S	✓			✓															
DOUBLE GYP SIZE 2	S								*✓	✓												3.16
DOUBLE GYP SIZE 3	S		S													✓						
GYPROCK SIZE 1		S				*✓				✓												3.17
GYPROCK SIZE 2	S	S	S																			
GYPROCK SIZE 3		S		✓						✓												
GLASS SIZE 1		S	S	✓																		
GLASS SIZE 2		S	S	✓																		
GLASS SIZE 3				✓			✓			✓												

Refer Section 3.7 for symbols

TABLE 3.9 Varying mounting orientation: source B.

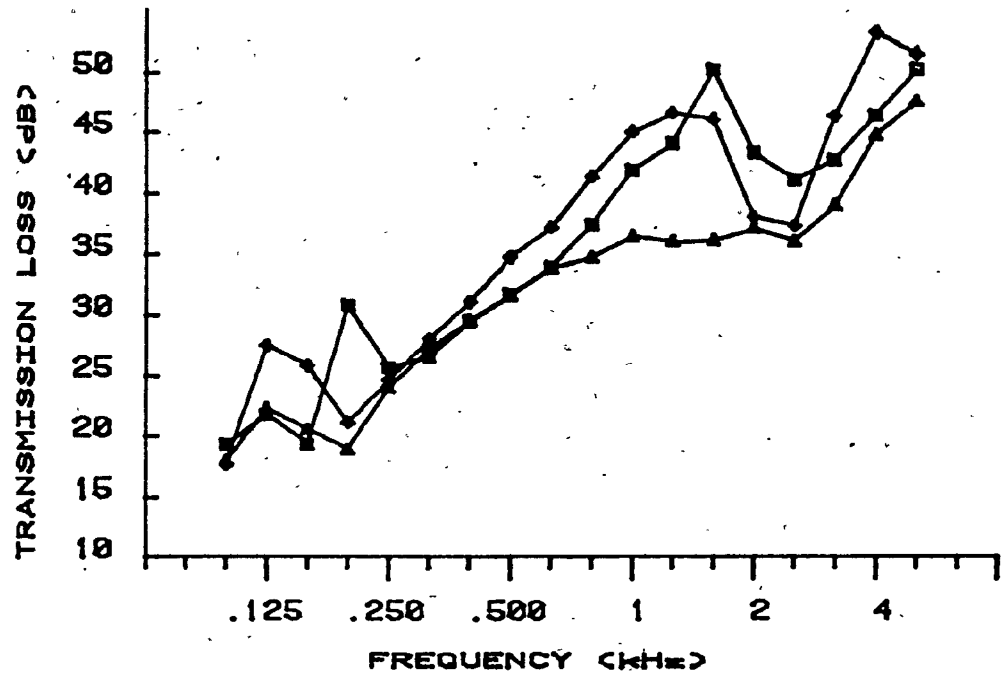
MATERIAL	SOURCE ROOM A																					* REFERENCE FIG. NO.
	a			MOUNTING ROOM B									MOUNTING ROOM A									
	I	II	III	I			II			III			I			II			III			
				b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	
DOUBLE GYP SIZE 1	S	S																	✓			
DOUBLE GYP SIZE 2		S		✓					✓													
DOUBLE GYP SIZE 3													* ✓				✓		✓			3.15
GYPROCK SIZE 1	S	S	S																			
GYPROCK SIZE 2	S	S	S																			
GYPROCK SIZE 3		S	S	✓																		
GLASS SIZE 1	S	S																	✓			
GLASS SIZE 2		S		✓															* ✓			3.18
GLASS SIZE 3				✓			✓			✓												

Refer section 3.7 for symbols

TABLE 3.10 Varying mounting orientation: source A.

TRANSMISSION LOSS (dB)

FREQ.(Hz)	◘	▲	◆
100	18.3	16.9	16.7
125	20.6	21.2	26.5
160	18.3	19.5	24.6
200	29.6	17.9	20.1
250	24.6	23.0	23.6
315	25.5	26.2	27.6
400	28.4	28.5	30.0
500	30.7	30.5	33.7
630	32.9	32.6	36.1
800	36.4	33.7	40.3
1000	40.6	35.3	43.9
1250	43.0	34.9	45.4
1600	49.1	35.1	44.9
2000	42.2	36.0	37.0
2500	40.0	34.9	36.2
3150	41.7	38.0	45.2
4000	45.3	43.6	52.0
5000	49.1	46.4	50.3



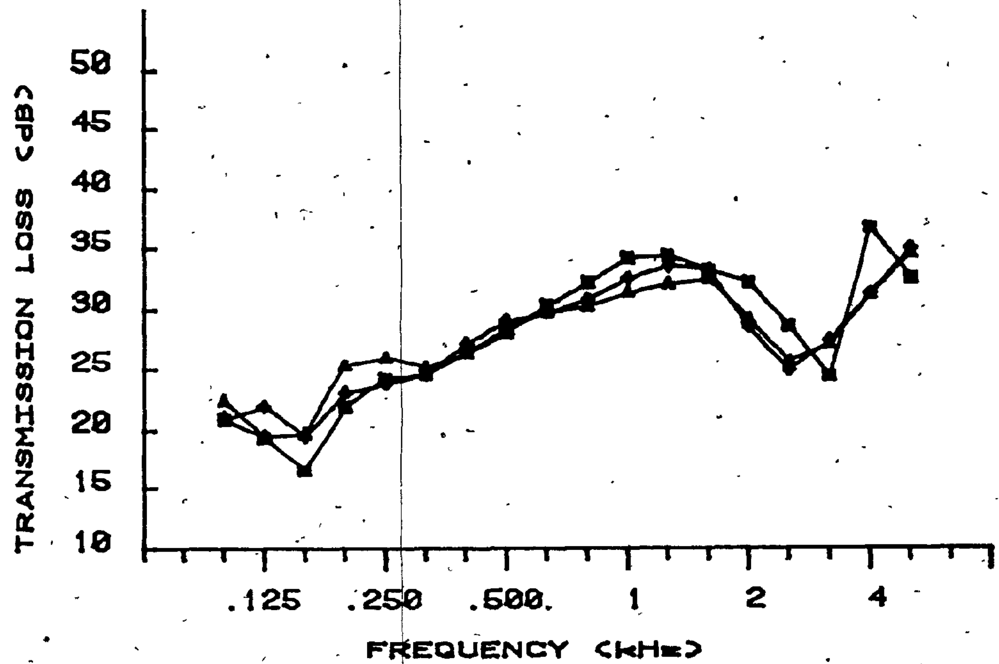
LEGEND

◘	0.54 sq. meter
▲	2.32 sq. meters
◆	3.93 sq. meters

FIG. 3.2 TL FOR DOUBLE GYPROCK PANELS, WITH DIFFUSERS, MOUNTED IN ROOM A, ROOM A SOURCE.

TRANSMISSION LOSS (dB)

FREQ. (Hz)	□	▲	◆
100	19.9	21.3	19.8
125	16.4	18.5	20.0
160	15.5	16.7	18.5
200	20.6	24.3	21.9
250	23.2	25.0	22.7
315	23.5	24.1	23.5
400	26.4	25.3	26.2
500	27.1	27.4	28.1
630	29.3	28.8	28.0
800	31.2	29.2	29.8
1000	33.1	30.4	31.5
1250	33.3	31.1	32.5
1600	32.1	31.5	32.2
2000	31.2	28.2	27.4
2500	27.6	24.6	23.8
3150	23.3	26.1	26.4
4000	35.6	30.2	30.2
5000	31.5	33.5	33.9



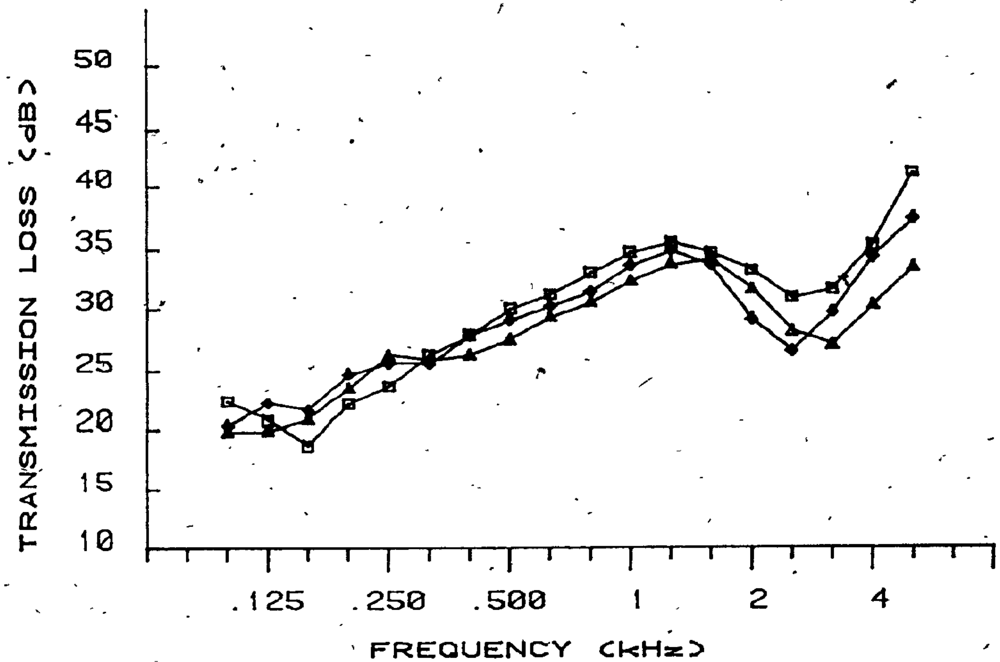
LEGEND

■—■ 0.54 sq. meter
▲—▲ 2.32 sq. meters
◆—◆ 3.93 sq. meters

FIG. 3.3 TL FOR GYPROCK PANELS, WITH DIFFUSERS, MOUNTED IN ROOM A, ROOM B SOURCE.

TRANSMISSION LOSS (dB)

FREQ.(Hz)	□	△	◇
100	21.2	18.8	19.2
125	19.6	18.9	21.0
160	17.6	19.7	20.4
200	21.0	22.4	23.7
250	22.6	25.3	24.6
315	25.3	24.9	24.6
400	26.8	25.3	26.8
500	29.0	26.5	28.0
630	30.1	28.3	29.2
800	32.0	29.5	30.3
1000	33.6	31.2	32.6
1250	34.4	32.6	33.7
1600	33.6	33.1	32.5
2000	32.2	30.6	28.0
2500	29.8	27.1	25.5
3150	30.6	26.1	28.6
4000	34.2	29.2	33.2
5000	40.1	32.4	36.2



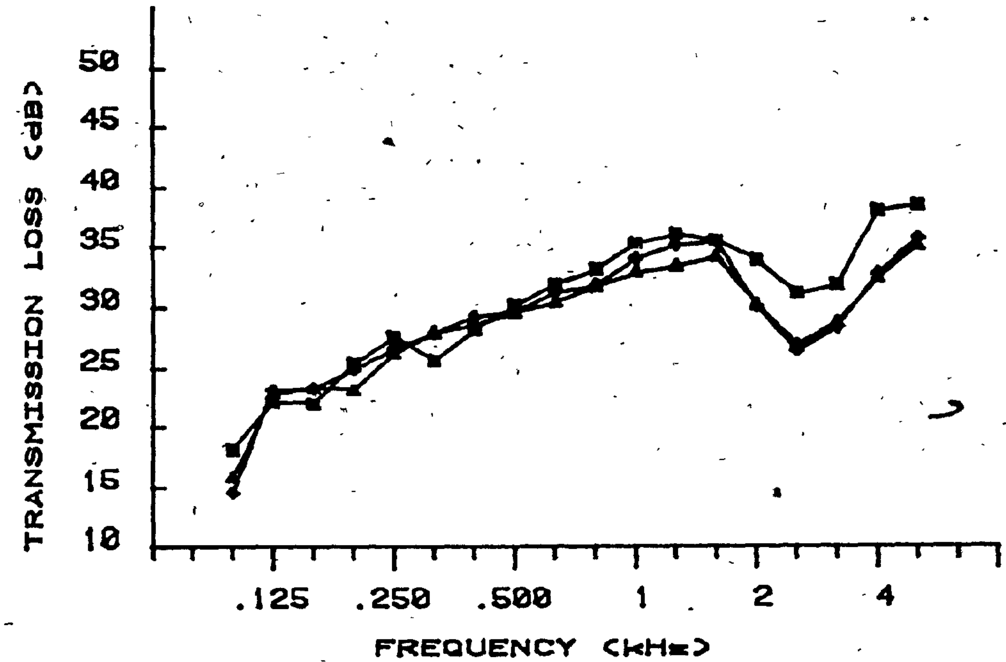
LEGEND

- □ 0.54 sq. meter
- △ 2.32 sq. meters
- ◇ 3.93 sq. meters

FIG. 3.4 TL FOR GYPROCK PANELS, WITH DIFFUSERS, MOUNTED IN ROOM B, ROOM B SOURCE.

TRANSMISSION LOSS (dB)

FREQ.(Hz)	▫	▲	◆
100	17.3	14.8	13.5
125	21.9	21.8	22.1
160	20.6	22.2	22.2
200	24.4	22.1	23.9
250	26.6	25.2	25.7
315	24.6	26.9	26.6
400	27.2	27.5	26.1
500	29.1	28.5	28.6
630	30.9	29.4	30.2
800	32.0	30.6	30.7
1000	34.1	31.6	32.9
1250	34.9	32.3	34.0
1600	34.4	33.0	34.3
2000	32.7	29.1	29.0
2500	30.1	25.9	25.4
3150	30.8	27.6	27.3
4000	36.9	31.3	31.6
5000	37.3	33.9	34.5



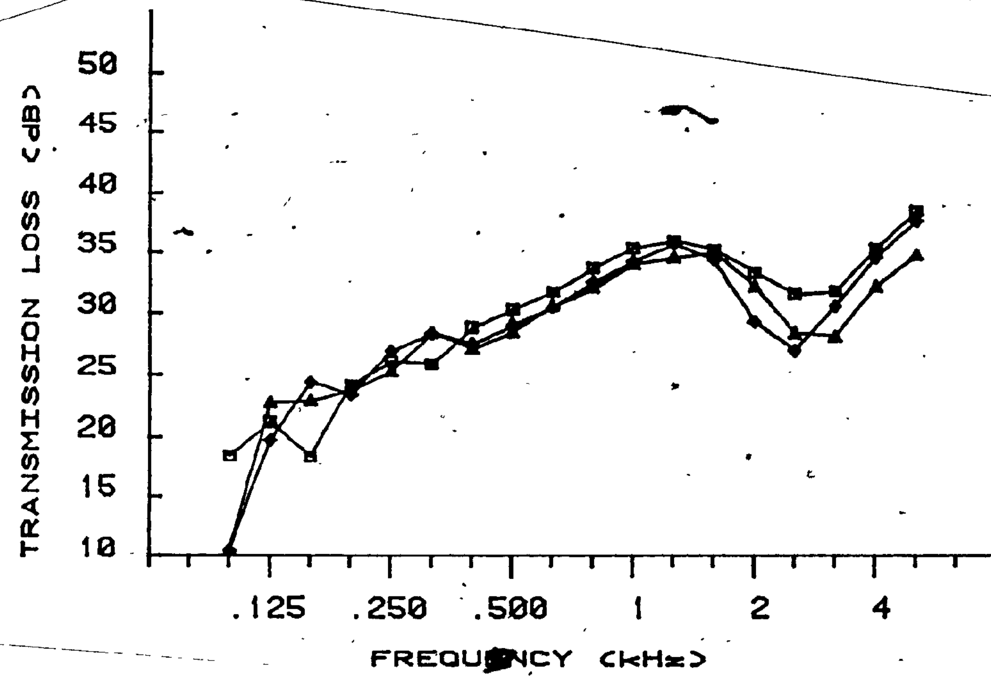
LEGEND

- ■ 0.54 sq. meter
- ▲ 2.32 sq. meters
- ◆ 3.93 sq. meters

FIG. 3.5 TL FOR GYPROCK PANELS, WITH DIFFUSERS, MOUNTED IN ROOM A, ROOM A SOURCE.

TRANSMISSION LOSS (dB)

FREQ.(Hz)	□	△	◇
100	17.4	9.5	9.5
125	20.2	21.7	18.6
160	17.3	21.8	23.3
200	23.1	22.7	22.3
250	25.1	24.2	26.0
315	24.8	27.4	27.4
400	27.8	26.1	26.5
500	29.2	27.5	28.0
630	30.6	29.5	29.4
800	32.6	31.0	31.5
1000	34.2	32.9	33.1
1250	34.9	33.4	34.6
1600	34.1	33.9	33.2
2000	32.2	31.1	28.2
2500	30.5	27.4	26.0
3150	30.7	27.1	29.5
4000	34.1	31.1	33.4
5000	37.4	33.7	36.6



LEGEND

- □ 0.54 sq. meter
- △ 2.32 sq. meters
- ◇ 3.93 sq. meters

FIG. 3.6 TL FOR GYPROCK PANELS, WITH DIFFUSERS, MOUNTED IN ROOM B, ROOM A SOURCE.

TRANSMISSION LOSS (dB)

FREQ. (Hz)	□	△	◇
100	21.2	18.8	19.2
125	19.6	18.9	21.0
160	17.8	19.7	20.4
200	21.0	22.4	23.7
250	22.6	25.3	24.6
315	25.3	24.9	24.6
400	26.8	25.3	26.8
500	29.0	26.5	28.0
630	30.1	28.3	29.2
800	32.0	29.5	30.3
1000	33.6	31.2	32.6
1250	34.4	32.6	33.7
1600	33.6	33.1	32.5
2000	32.2	30.6	28.0
2500	29.8	27.1	25.5
3150	30.6	26.1	28.6
4000	34.2	29.2	33.2
5000	40.1	32.4	36.2

LEGEND

- ■ 0.54 sq. meter
- ▲ 2.32 sq. meters
- ◆ 3.93 sq. meters

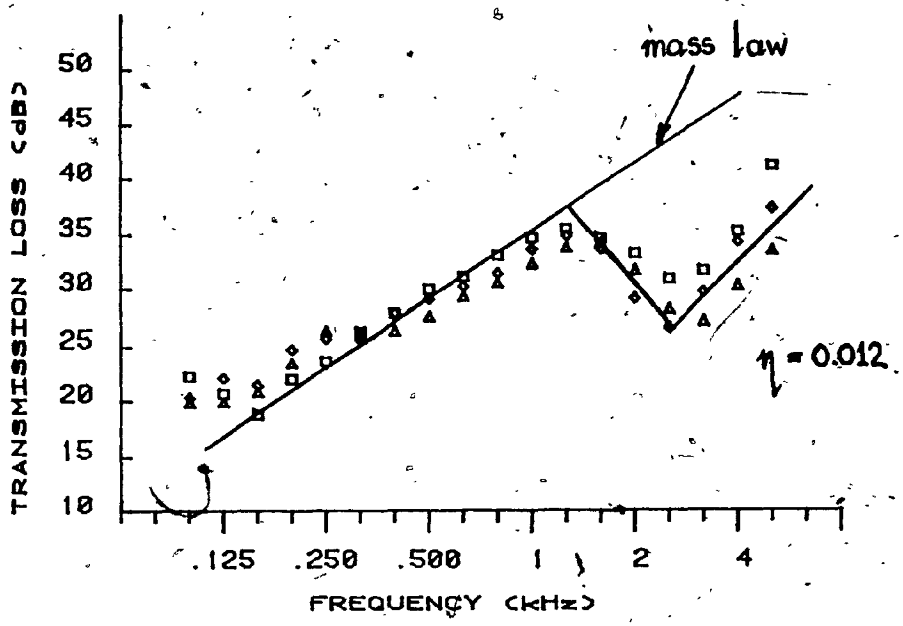
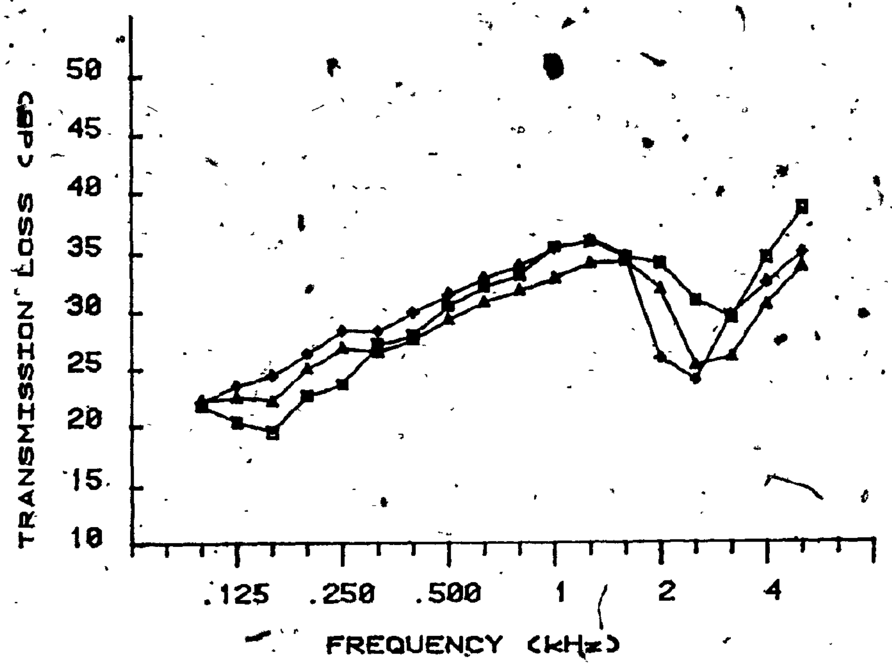


FIG. 3.7 TL FOR GYPROCK PANELS, WITH DIFFUSERS, MOUNTED IN ROOM B, ROOM B SOURCE.

TRANSMISSION LOSS (dB)

FREQ. (Hz)	□	▲	◆
100	20.6	21.1	21.0
125	19.3	21.3	22.5
160	18.4	21.0	23.3
200	21.5	23.9	25.3
250	22.5	25.8	27.3
315	26.1	25.4	27.2
400	26.9	26.5	28.8
500	29.4	28.2	30.4
630	31.1	29.8	31.7
800	32.0	30.7	32.7
1000	34.4	31.7	34.2
1250	34.9	33.0	35.1
1600	33.5	33.1	33.6
2000	32.9	30.8	24.8
2500	29.8	24.1	22.8
3150	28.3	24.9	28.6
4000	33.4	29.5	31.6
5000	37.6	32.7	33.8



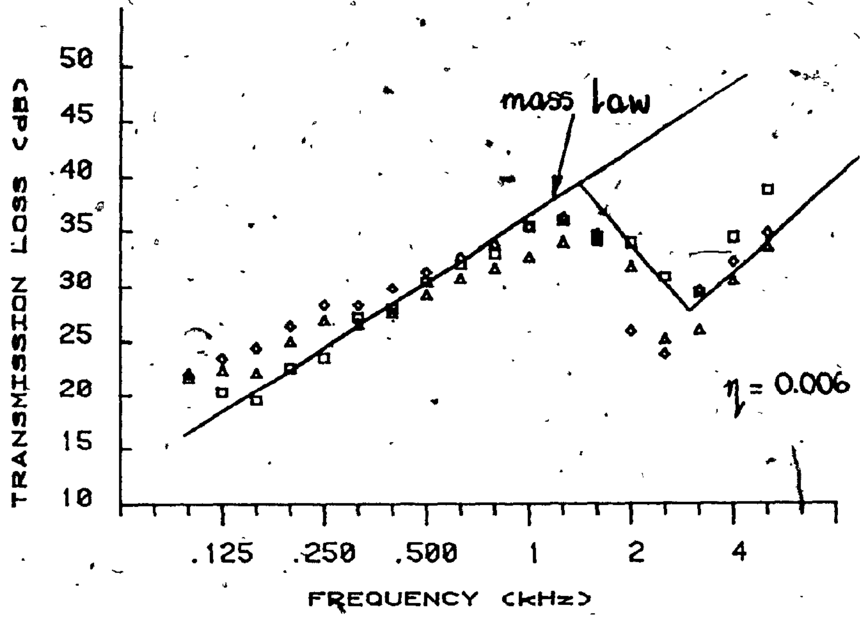
LEGEND

□—□ 0.54 sq. meter
▲—▲ 2.32 sq. meters
◆—◆ 3.93 sq. meters

FIG. 3.8 TL FOR GLASS PANELS, WITH DIFFUSERS, MOUNTED IN ROOM B, ROOM B SOURCE.

TRANSMISSION LOSS (dB)

FREQ. (Hz)	□	△	◇
100	20.6	21.1	21.0
125	19.3	21.3	22.5
160	18.4	21.0	23.3
200	21.5	23.9	25.3
250	22.5	25.8	27.3
315	26.1	25.4	27.2
400	26.9	26.5	28.8
500	29.4	28.2	30.4
630	31.1	29.8	31.7
800	32.0	30.7	32.7
1000	34.4	31.7	34.2
1250	34.9	33.0	35.1
1600	33.5	33.1	33.6
2000	32.9	30.8	24.8
2500	29.6	24.1	22.8
3150	28.3	24.9	28.6
4000	33.4	29.5	31.3
5000	37.6	32.7	33.8



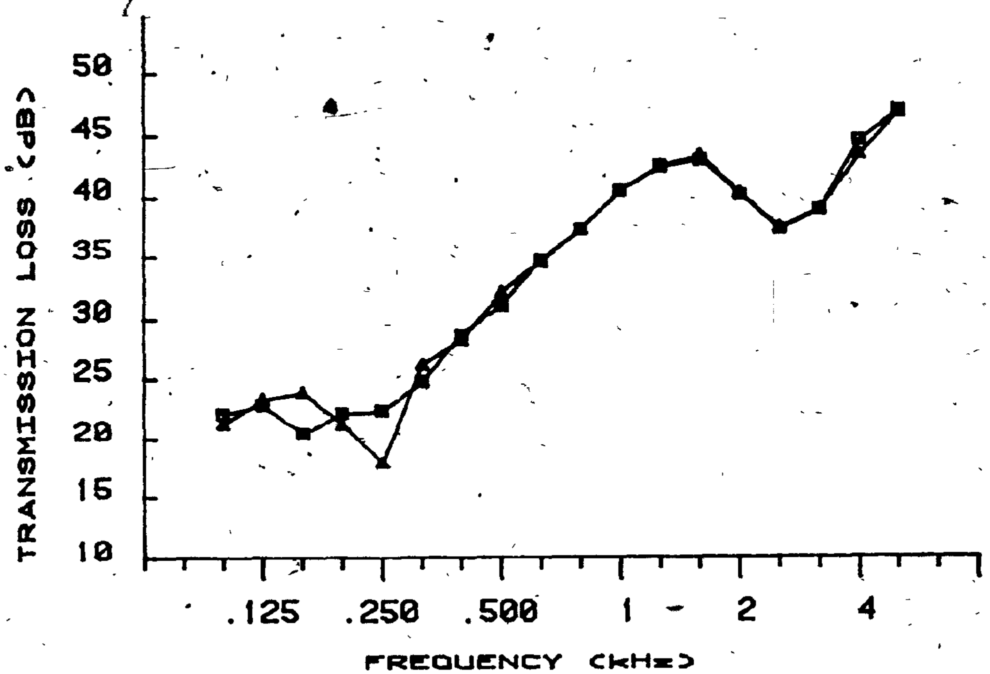
LEGEND

- □ 0.54 sq. meter
- △ 2.32 sq. meters
- ◇ 3.93 sq. meters

FIG. 3.9 TL FOR GLASS PANELS, WITH DIFFUSERS, MOUNTED IN ROOM B, ROOM B SOURCE.

TRANSMISSION LOSS (dB)

FREQ. (Hz)	□	▲
100	21.1	20.3
125	21.6	22.3
160	19.5	22.6
200	21.1	20.2
250	21.4	18.8
315	23.7	25.1
400	27.6	27.1
500	30.1	31.1
630	33.0	33.5
800	36.3	36.3
1000	39.4	39.5
1250	41.3	41.4
1600	41.9	42.2
2000	39.1	39.2
2500	36.2	36.4
3150	37.9	37.9
4000	43.4	42.2
5000	45.9	45.7



LEGEND

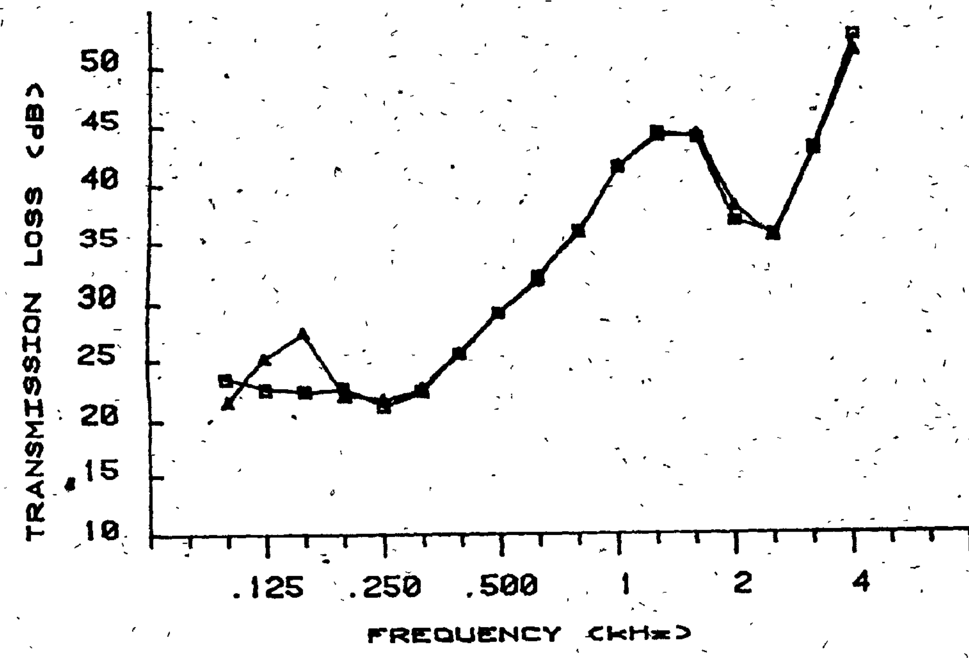
■———■ 2.32 sq. meters with diffusers

▲———▲ 2.32 sq. meters without diffusers

FIG. 3.10 TL FOR DOUBLE GYPROCK PANELS, MOUNTED IN ROOM B, ROOM B SOURCE.

TRANSMISSION LOSS (dB)

FREQ. (Hz)	□	▲
100	22.4	20.5
125	21.6	24.1
160	21.4	26.4
200	21.6	21.0
250	20.2	20.8
315	21.4	21.6
400	24.5	24.6
500	28.1	28.1
630	30.9	31.0
800	35.0	34.6
1000	40.3	40.4
1250	43.1	42.6
1600	42.7	43.0
2000	35.8	37.1
2500	34.6	34.2
3150	41.8	41.6
4000	51.3	50.0
5000	0.0	0.0



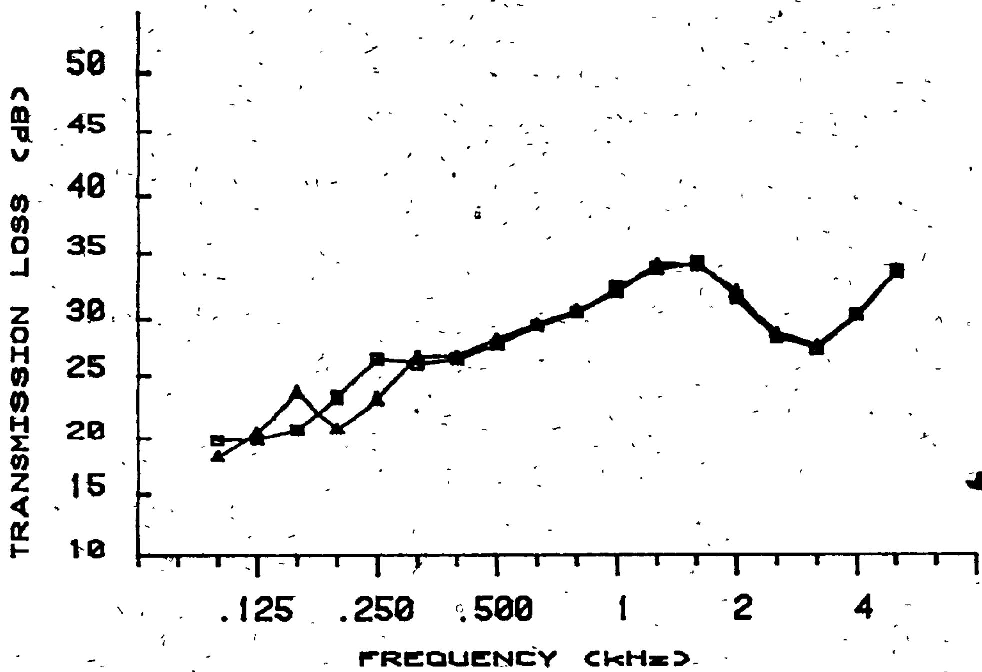
LEGEND

■—■ 3.93 sq. meters with diffusers
▲—▲ 3.93 sq. meters without diffusers

FIG. 3.11 TL FOR DOUBLE GYPROCK PANELS, MOUNTED IN ROOM B, ROOM B SOURCE.

TRANSMISSION LOSS (dB)

FREQ. (Hz)	□	▲
100	19.6	17.2
125	19.9	19.5
160	19.7	22.6
200	22.4	19.6
250	25.3	22.9
315	24.9	25.5
400	25.3	25.5
500	26.5	27.1
630	[illegible].3	28.4
800	29.5	29.7
1000	31.2	31.0
1250	32.6	33.0
1600	33.1	32.9
2000	30.6	30.9
2500	27.1	27.6
3150	28.1	28.4
4000	29.2	29.9
5000	32.4	32.4



LEGEND

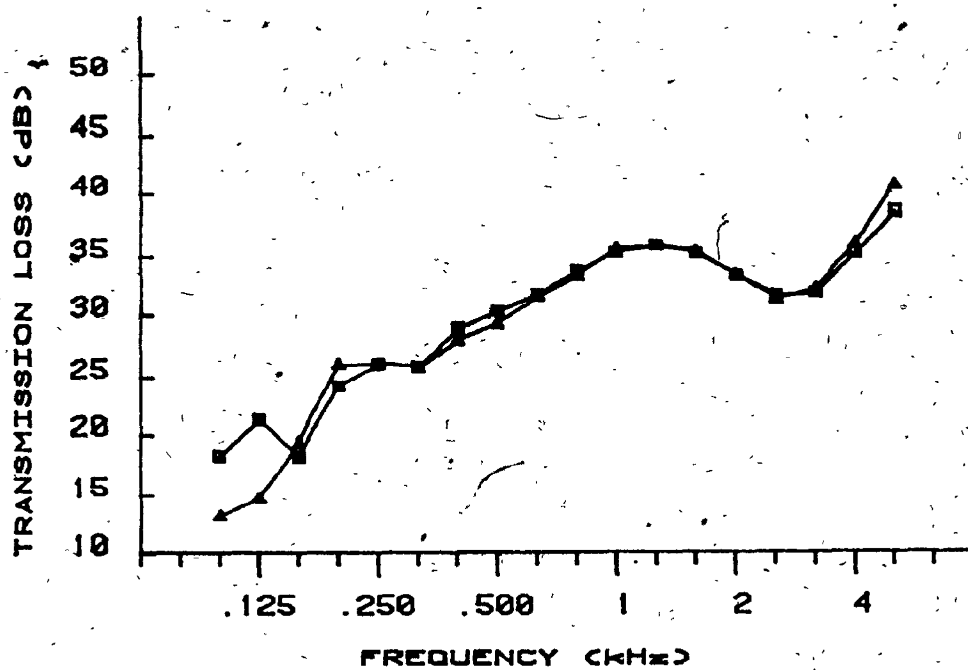
■——■ 2.32 sq. meters with diffusers

▲——▲ 2.32 sq. meters without diffusers

FIG. 3.12 TL FOR GYPROCK PANELS,
MOUNTED IN ROOM B, ROOM B SOURCE.

TRANSMISSION LOSS (dB)

FREQ.(Hz)	□	▲
100	17.4	12.1
125	20.2	13.7
160	17.3	16.4
200	23.1	25.1
250	25.1	25.2
315	24.6	24.6
400	27.6	27.0
500	29.2	28.2
630	30.6	30.5
800	32.6	32.2
1000	34.2	34.6
1250	34.9	34.6
1600	34.1	34.3
2000	32.2	32.3
2500	30.5	30.2
3150	30.7	31.1
4000	34.1	35.0
5000	37.4	39.6



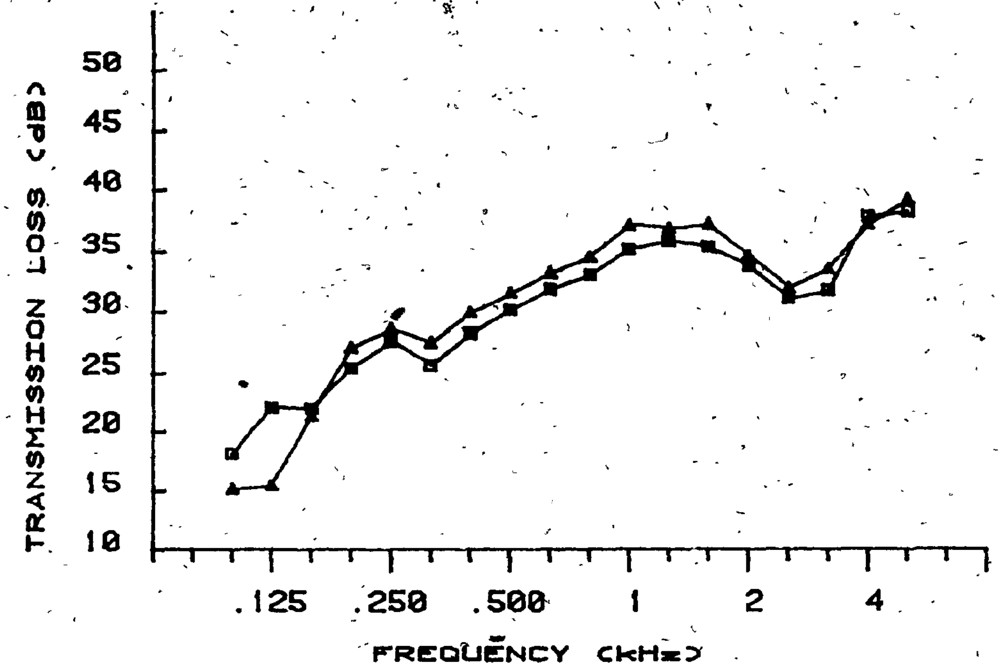
LEGEND

■——■ 0.54 sq. meter with diffusers
▲——▲ 0.54 sq. meter without diffusers

FIG. 3.13 TL FOR GYPROCK PANELS,
MOUNTED IN ROOM B, ROOM A SOURCE.

TRANSMISSION LOSS (dB)

FREQ.(Hz)	□	▲
100	17.3	14.1
125	21.0	14.4
160	20.6	20.2
200	24.4	26.0
250	26.6	27.5
315	24.6	26.4
400	27.2	28.9
500	29.1	30.5
630	30.9	32.2
800	32.0	33.5
1000	34.1	36.2
1250	34.9	36.0
1600	34.4	36.3
2000	32.7	33.7
2500	30.1	30.9
3150	30.6	32.5
4000	36.9	36.2
5000	37.3	38.1



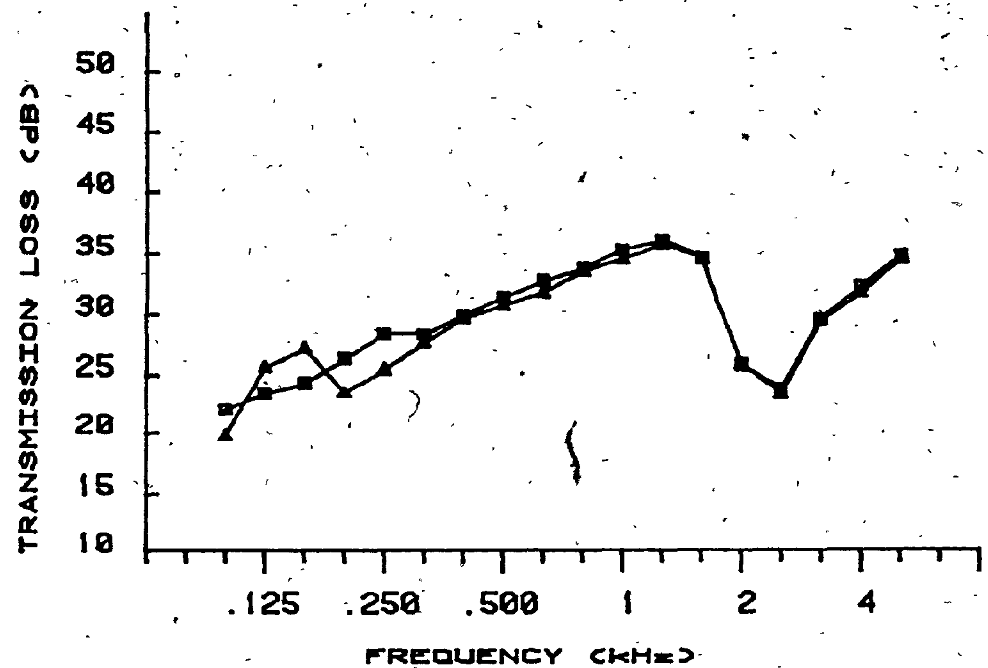
LEGEND

□——■ 0.54 sq. meter with diffusers
▲——▲ 0.54 sq. meter without diffusers

FIG. 3.14 TL FOR GYPROCK PANELS,
MOUNTED IN ROOM A, ROOM A SOURCE.

TRANSMISSION LOSS (dB)

FREQ. (Hz)	◻	▲
100	21.0	18.8
125	22.5	24.8
160	23.3	26.1
200	25.3	22.5
250	27.3	24.4
315	27.2	26.6
400	28.6	28.5
500	30.4	29.8
630	31.7	30.8
800	32.7	32.5
1000	34.2	33.5
1250	35.1	34.7
1600	33.6	33.5
2000	24.6	24.8
2500	22.8	22.3
3150	28.6	28.3
4000	31.3	30.8
5000	33.8	33.5



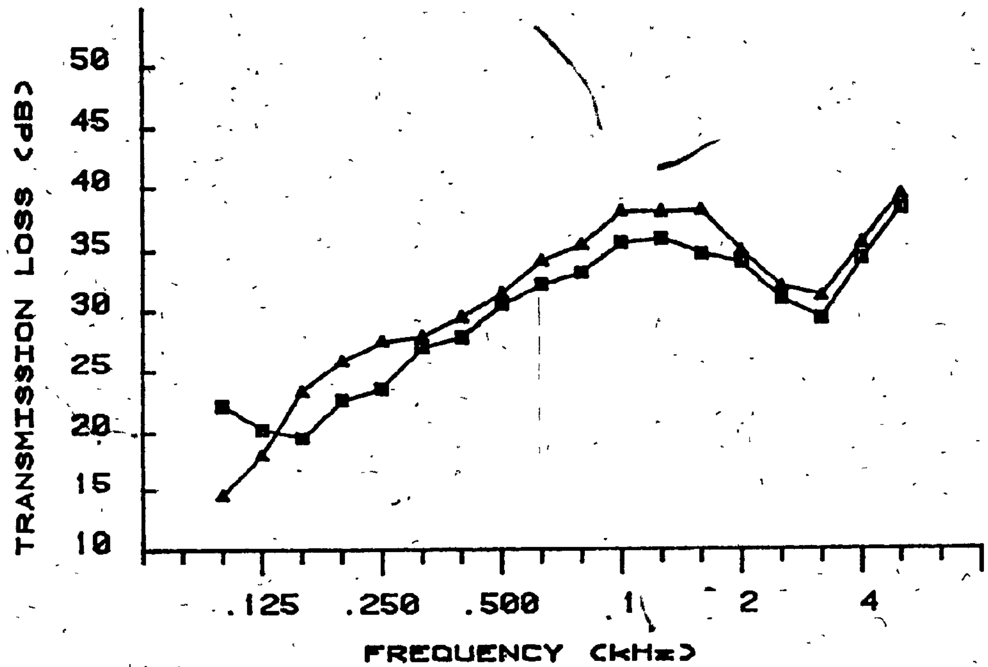
LEGEND

■—■ 3.93 sq. meters with diffusers
▲—▲ 3.93 sq. meters without diffusers

FIG. 3.15 TL FOR GLASS PANELS,
MOUNTED IN ROOM B, ROOM B SOURCE.

TRANSMISSION LOSS (dB)

FREQ. (Hz)	◻	▲
100	21.1	13.5
125	19.2	17.0
160	18.5	22.2
200	21.5	24.9
250	22.5	26.6
315	26.1	27.0
400	26.9	28.5
500	29.4	30.4
630	31.1	33.1
800	32.2	34.4
1000	34.5	36.9
1250	34.6	36.9
1600	33.6	37.0
2000	32.9	33.9
2500	29.6	30.9
3150	28.3	30.1
4000	33.2	34.5
5000	37.2	38.3



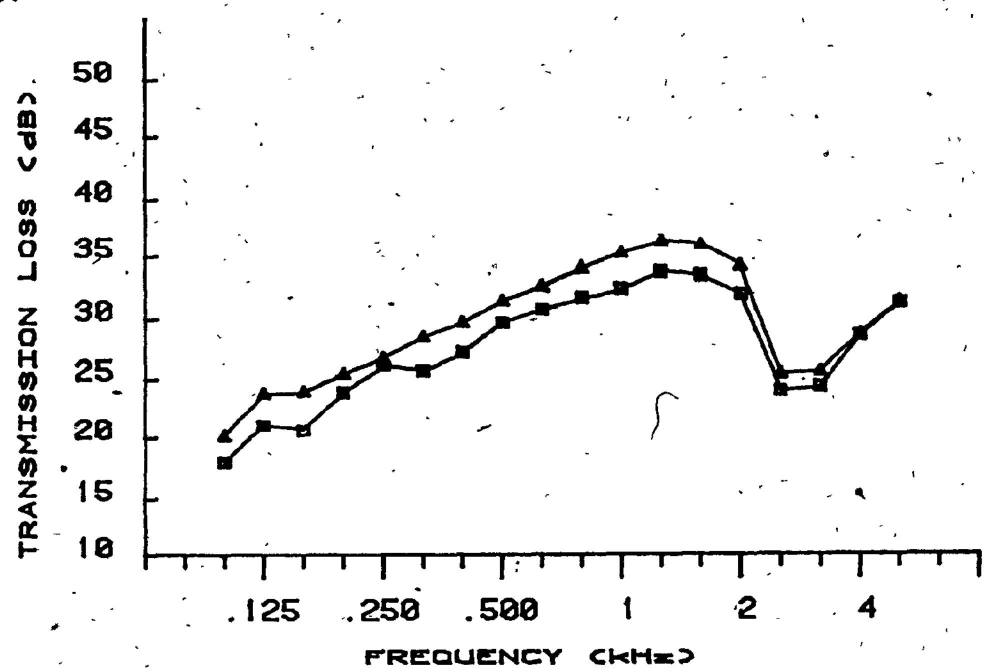
LEGEND

◻—◻ 0.54 sq. meter with diffusers
▲—▲ 0.54 sq. meter without diffusers

FIG. 3.16 TL FOR GLASS PANELS,
MOUNTED IN ROOM B, ROOM A SOURCE.

TRANSMISSION LOSS (dB)

FREQ.(Hz)	■	▲
100	17.1	19.1
125	20.0	22.6
160	19.6	22.9
200	22.9	24.4
250	25.1	25.7
315	24.6	27.4
400	26.1	28.6
500	28.6	30.5
630	29.7	31.6
800	30.7	33.0
1000	31.4	34.2
1250	32.7	35.2
1600	32.4	34.9
2000	31.0	33.2
2500	23.0	24.4
3150	23.3	24.5
4000	27.5	27.6
5000	30.3	30.4



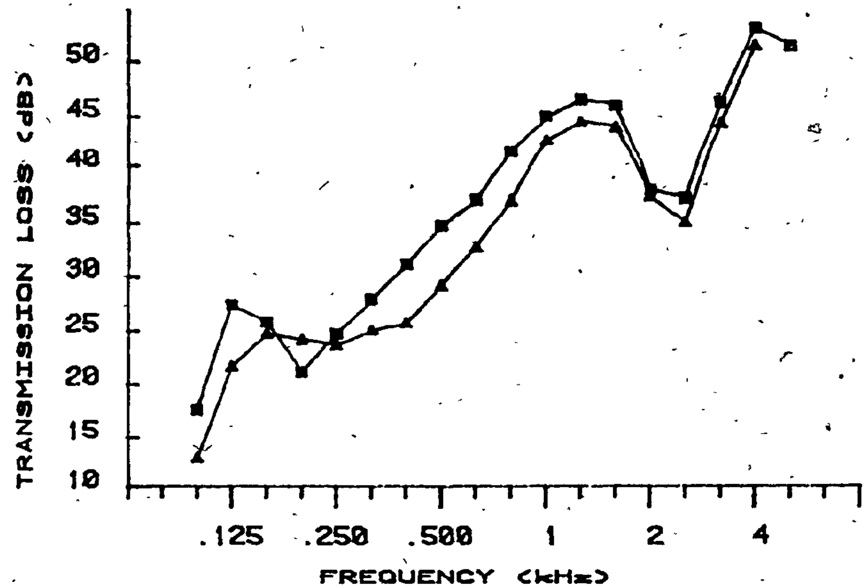
LEGEND

- ■—■ 2.32 sq. meters with diffusers
- ▲—▲ 2.32 sq. meters without diffusers

FIG. 3.17 TL FOR GLASS PANELS,
MOUNTED IN ROOM A, ROOM B SOURCE.

TRANSMISSION LOSS (dB)

FREQ. (Hz)	■	▲
100	16.7	11.8
125	26.5	20.6
160	24.6	23.7
200	20.1	23.1
250	23.6	22.6
315	27.0	24.0
400	30.8	24.7
500	33.7	28.2
630	36.1	31.6
800	40.3	36.0
1000	43.9	41.4
1250	45.4	43.4
1600	44.9	42.6
2000	37.0	36.4
2500	36.2	34.0
3150	45.2	43.2
4000	52.0	50.3
5000	50.3	55.9



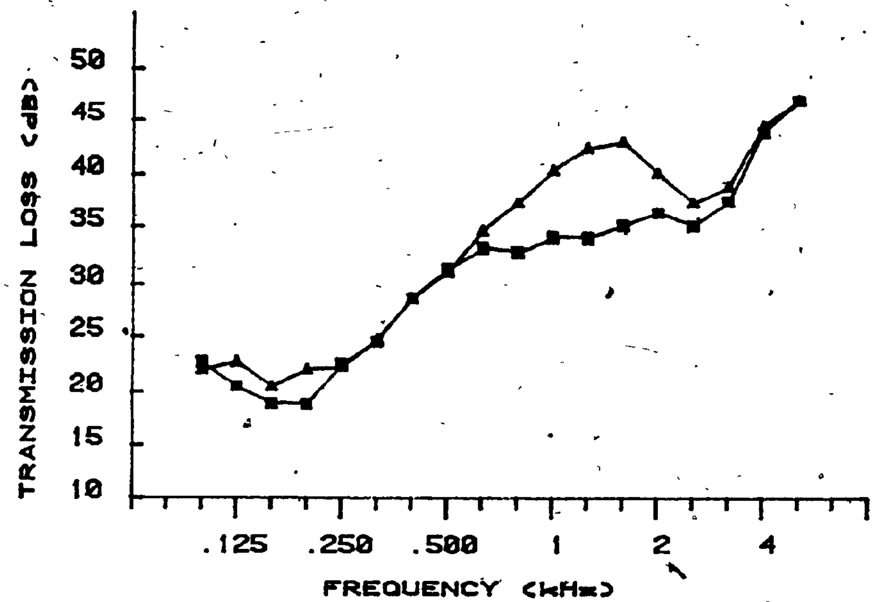
LEGEND

■——■ 3.93 sq. meters, mounted in A
▲——▲ 3.93 sq. meters, mounted in B

FIG. 3.18 TL FOR DOUBLE GYPROCK PANELS, WITH DIFFUSERS, ROOM A SOURCE.

TRANSMISSION LOSS (dB)

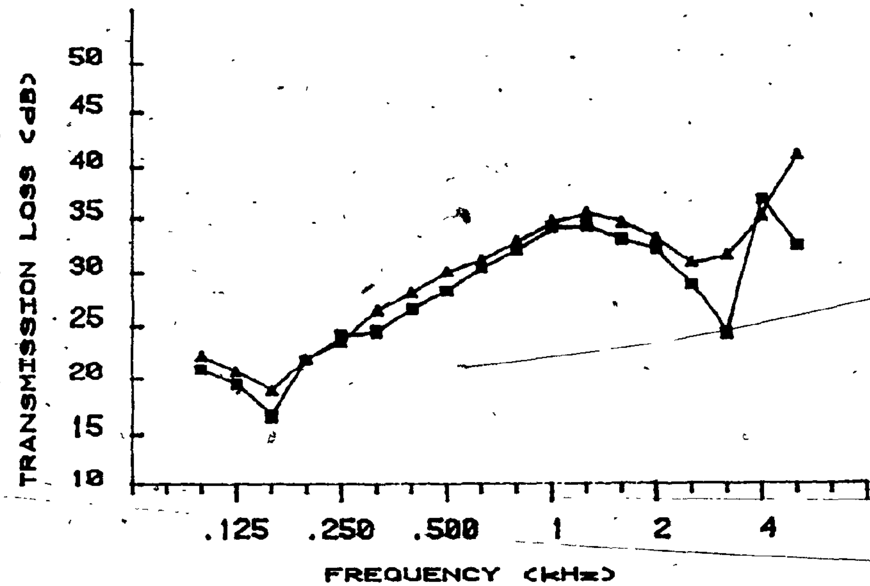
FREQ. (Hz)	■	▲
100	21.8	21.1
125	19.5	21.8
160	17.9	19.5
200	17.8	21.1
250	21.6	21.4
315	23.5	23.7
400	27.6	27.6
500	30.4	30.1
630	32.2	33.6
800	31.6	36.3
1000	33.1	39.4
1250	33.0	41.3
1600	34.1	41.9
2000	35.9	39.1
2500	34.1	36.2
3150	36.4	37.9
4000	42.6	43.4
5000	45.8	45.9



LEGEND

■——■ 2.32 sq. meters, mounted in A
▲——▲ 2.32 sq. meters, mounted in B

FIG. 3.19 TL FOR DOUBLE GYPROCK PANELS, WITH DIFFUSERS, ROOM B SOURCE.



TRANSMISSION LOSS (dB)

FREQ. (Hz)	■	▲
100	19.9	21.2
125	18.4	19.6
160	15.5	17.6
200	20.8	21.0
250	23.2	22.6
315	23.5	25.3
400	25.4	26.8
500	27.1	29.0
630	29.3	30.1
800	31.2	32.0
1000	33.1	33.6
1250	33.3	34.4
1600	32.1	33.6
2000	31.2	32.2
2500	27.6	29.6
3150	23.3	30.6
4000	35.6	34.2
5000	31.5	40.1

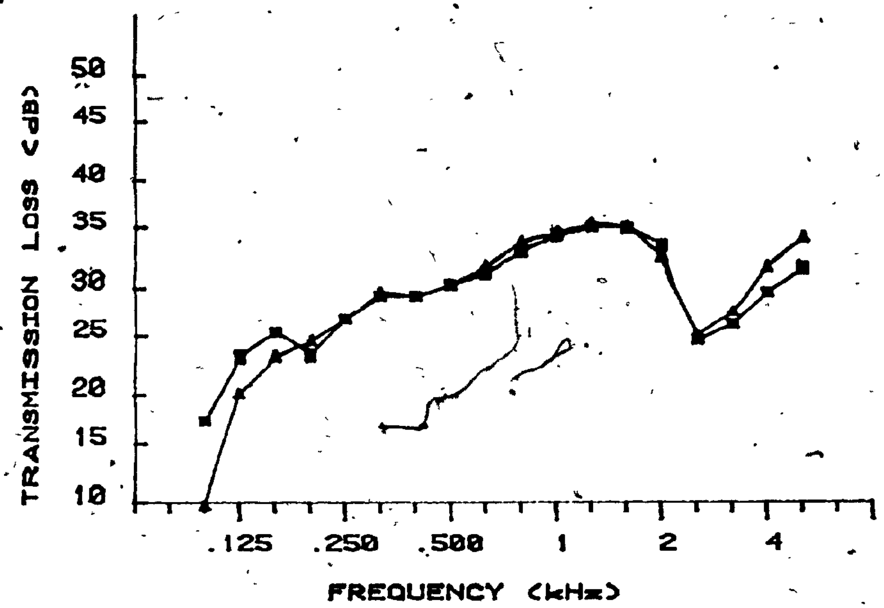
LEGEND

■——■ 0.54 sq. meter, mounted in A,
▲——▲ 0.54 sq. meter, mounted in B

FIG. 3.20 TL FOR GYPROCK PANELS, WITH DIFFUSERS,
ROOM B SOURCE.

TRANSMISSION LOSS (dB)

FREQ. (Hz)	■	▲
100	16.2	6.7
125	22.2	19.1
160	24.3	22.2
200	22.3	23.5
250	25.7	25.7
315	26.1	26.6
400	28.1	28.1
500	29.2	29.2
630	30.2	30.6
800	32.8	32.7
1000	33.3	33.5
1250	34.0	34.3
1600	33.9	33.9
2000	32.4	31.5
2500	23.5	23.9
3150	25.1	26.4
4000	28.4	30.7
5000	30.5	33.0



LEGEND

■——■ 2.32 sq. meters, mounted in A
▲——▲ 2.32 sq. meters, mounted in B

FIG. 3.21 TL FOR GLASS PANELS, WITH DIFFUSERS, ROOM A SOURCE.

CHAPTER IV

CONCLUSIONS, GUIDELINES AND RECOMMENDATIONS

4.1 CONCLUSIONS

From the results that are obtained concerning the measured transmission loss of panels when mounting conditions are kept constant the following conclusions can be made:

a) Frequencies above coincidence

The transmission loss of a panel is largely independent of diffusing conditions and room dimensions, which is in agreement with theory, but is found to depend on panel area (not in agreement with previous literature). Mounting orientation is found to have a slight effect on the transmission loss of glass panels but not on the gyprock panels indicating a direct relation between panel material and mounting orientation and their effect on transmission loss.

b) Frequencies between coincidence and room cut off

The transmission loss in this region is found to be independent of diffusing conditions which is in agreement with theory. A dependence on mounting orientation is noted especially for the double gyprock panels.

When panel dimensions are varied, it is evident from the results that the TL is affected, that each material acts in a different manner and that only panel size 2 depicts a trend, in that, for almost every case it has the lowest measured TL.

The test results for double gyprock panels, show that the larger panel (size 3) has a higher TL, which is in agreement with previous literature[3], but this is true only when mounting orientation is in room A. Also, at higher frequencies (below coincidence), the medium sized panel (size 2) has a lower TL than the smallest panel (size 1) which disagrees with reported findings. When mounting orientation is in room B, panel size 3 has the lowest measured TL, which again disagrees with other documented results, but shows that the panel is dependant on mounting position. As discussed in the analysis chapter these variations are related to panel construction.

c) Frequencies below the room cut-off

In this frequency region, as expected, all parameters introduced have an effect on the measured TL which is in agreement with theory. In the low frequencies the least dependence is found when mounting orientation is varied.

It should be kept in mind, however, that in this frequency range the measurements cannot be relied upon since the reverberant sound field is usually considered statistically unreliable below the Schroeder cut-off.

d) Critical Frequency

The measured critical frequency of the materials seems to be dependent on two parameters; mounting orientation and panel dimensions. Whereas varying the panel area does not affect the frequency at which coincidence occurs, it does affect the depth of the dip. Mounting orientation causes a shift in the critical frequency of gyprock panels.

From comparison of the results it is found that the variation in critical frequency that occurs for the glass panels cannot be explained.

4.2 GUIDELINES

It is evident from the experimental results and from the conclusions presented that the measured transmission loss of panels is dependent on the room parameters which may explain the reported differences between Laboratories on tests of similar panels.

Certain guidelines will have to be set in order to achieve minimum differences between results of laboratories when measuring the TL of panels. These guidelines should include the reporting of conditions present in a test room in order to correct the data accordingly when comparisons or analysis of results from a number of laboratories have to be made. The adjustment in results will have to be made through a correction factor on the transmission loss equation. To quantify the correction factor further investigations are required.

When preparing reports the following should also be included:

i) the size of panel used and its internal loss factor (damping), determined from decay measurements when excitation by a shaker attached on the panel is abruptly terminated.

ii) the receiving room dimensions and its absorption determined from reverberation measurements.

iii) the diffuseness of the sound field in the room investigated as per ASTM C 423

iv) the mounting orientation or the position of the panel between the two rooms with respect to the receiving room.

v) the microphone positions or sweep relative to room boundaries

vi) the mounting conditions of the panel

vii) the source position

4.3 RECOMMENDATIONS FOR FUTURE RESEARCH

In view of the behaviour of the measured transmission loss of the panels, the following recommendations are suggested for future research:

a) A similar investigation in other laboratories to gather sufficient data from which appropriate normalization procedures can be derived so that TL measurements between laboratories can be made to agree.

b) Measurement of the TL of panels in field conditions and comparison or correlation between laboratory and field results.

c) A comparison of the measured TL of larger sized panels with the smaller panels tested.

d) An investigation of the performance of the rotating diffuser and its effect on diffusion in the reverberation chamber.

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APPENDIX A

TRANSMISSION LOSS PROGRAM SOFTWARE

(written in HPL)

REVERBERATION PROGRAM

```
0: dim G[18],B[18],B$[318],W[18],N$[6],S$[1],V$[8]
1: dim P[45,18],X[18],Q[18]
2: dim A$[6615],Y[18],Z[18],D$[80]
3: dim R$[1],T$[2],U$[2],S[18],T[18],L[18]
4: 100}W[1];125}W[2];160}W[3];200}W[4];250}W[5];315}W[6];400}W[7]
5: 500}W[8];630}W[9];800}W[10];1000}W[11];1250}W[12];1600}W[13]
6: 2000}W[14];2500}W[15];3150}W[16];4000}W[17];5000}W[18]
7: wrt 717,"OBN:M?L>";wait 100;lcl 7;wait 1000
8: cll 'input'
9: 1}U
10: cll 'set'(U)
11: T$[1,2]}U$[1,2];650-(10+10num(U$[2,2]))}V
12: buf "in",R$,3
13: cll 'lin'
14: B$[134,280]}A$[1,147]
15: for I=1 to 18;val(A$[7I-6,7I])}T[I];next I
16: rem 7;wait 3000
17: wrt 717,"N>";wait 1000
18: "N>"}T$
19: cll 'lin'
20: B$[134,280]}A$[1,147]
21: for I=1 to 18;val(A$[7I-6,7I])}L[I]
22: if L[I]<V;V+5}L[I]
23: next I
24: clr 7;wait 100;cli 7;wait 100
25: wrt 717,U$;wait 50;lcl 7
26: wrt 717,"04";wait 5000
27: for R=1 to 50
28: dsp R
29: cll 'time'
30: for I=1 to 18;for J=1 to 45;147J+7I-153}X;X+6}Y
31: tn^(val(A$[X,Y])/10)+P[J,I]}P[J,I];next J;next I
32:
33: next R
34: R-1}R
35: for I=1 to 18;for J=1 to 45;90I-90+2J}X;X+1}Y
36: 10log(P[J,I]/R)}P[J,I]
37: next J;next I
38: for I=1 to 18
39: 0}M}L}C}D}E}N
40: for K=5 to 43
41: if P[K,I]+5>T[I];gto 47
42: if P[K+1,I]+5>T[I] or P[K+2,I]>T[I];gto 47
43: if P[K,I]<L[I];gto 49
44: N+1}N
45: M+P[K,I]}M;L+.0625*N}L;E+.0625*N*P[K,I]}E
46: C+P[K,I]^2}C;D+(.0625*N)^2}D
47: next K
48: fxd 8
49: (E-M*L/N)/(D-L^2/N)}B
50: if B>=0;0}X[I];gto 55
51: (C-M^2/N-B*(E-M*L/N))/((N-2)*(D-L^2/N))}S
52: B^2}B[I];-B}X[I];N}Y[I];K-N-1}Z[I];S}S[I]
53: if K=44;43-N-1}Z[I]
54: 196*\S[I]/(X[I]*\R)}S[I]
55: next I
56: U+1}U
57: ent "ent 1 to  display spectra",r1;if r1=1;cll 'display'
58: cll 'out1'
59: set "tlset",0,0
60: end
61: "set":
62: "N:"}T$
63: if U=1;lcl 7;wait 1000
64: wrt 717,T$;wait 1000
65: ret T$
66: "time":
67: lcl 7;wait 5000
68: for J=1 to 45
```

```
69: wrt 717,'E?'
70: buf 'in'
71: tfr 716,'in',302
72: jmp rds('in')#-1
73: if J=5;rem 7
74: wrt 717,'E='
75: wait .01858
76: B$[134,280]→A$[147J-146,147J]
77: next J
78: ret A$
79: 'lin':
80: if U=1 or U=0;U-1→U
81: clr 7;wait 50;cli 7;wait 50
82: if U=-1;wrt 717,T$;wait 50;gto 84
83: wrt 717,U$;wait 50
84: if U#-1;lcl 7;wait 5000
85: wrt 717,'M?D;L?';wait 7000
86: wrt 717,'E?';wait 100
87: buf 'in'
88: tfr 716,'in',302
89: jmp rds('in')#-1
90: wrt 717,'E=';wait 100
91: wrt 717,'M?D3L>'
92: rem 7
93: if U=-1;U+2→U
94: ret B$
95: 'display':
96: 1→I
97: 'A':I-1→I;gto 99
98: 'B':I+1→I
99: clr 7;wait 500;cli 7;wait 500
100: wrt 717,'F>J?'
101: fmt 1,fz5.1
102: wrt 716.1,V-10
103: if I=0;1→I
104: if I=19;18→I
105: for J=1 to 42;wrt 716.1,P[J,I];next J
106: fxd 0;dsp 'TIMEAXIS AT',W[I],'HZ.';fxd-1
107: for J=1 to Z[I];wrt 717,'D>';wait 50;next J
108: for K=1 to 3
109: if Z[I]+Y[I]>30;cll 'two';gto 113
110: for J=1 to Y[I]-1;wrt 717,'D>';wait 50;next J;wait 500
111: for J=1 to Y[I]-1;wrt 717,'D?';wait 50;next J;wait 500
112: next K
113: dsp 'USE F2 & F3 FOR OTHER TIMEAXES';stp
114: gto 99
115: 'C':
116: ret
117: 'two':
118: for K=1 to 3
119: for W=1 to 29-Z[I];wrt 717,'D>';wait 50;next W
120: wrt 717,'J>'
121: for W=1 to Z[I]+Y[I]-30;wrt 717,'D>';wait 50;next W;wait 500
122: for W=1 to Z[I]+Y[I]-30;wrt 717,'D?';wait 50;next W
123: wrt 717,'J?'
124: for W=1 to 29-Z[I];wrt 717,'D?';wait 50;next W;wait 500
125: next K
126: ret
127: 'input':
128: asgn 'ABSDAT',1,0,X
129: setk 'keys'
130: dsp 'CALIBRATE & INITIALIZE SYSTEM';wait 100;beep;stp
131: fmt 4,c80
132: ent 'TEST TITLE',D$;wrt 4.4,D$
133: wtb 4,10;wtb 4,10
134: ent 'RECIEVING ROOM VOLUME M^2',H
135: ent 'SOURCE ROOM A or B',S$
136: ent 'TEST PANEL AREA',G
137: ent 'FINAL STORAGE FILE',N$
138: ent 'TEMP. IN DEG F',F
139: ent 'DATE MM/DD/YY',V$
140: fmt 5,6x,c5,2x,c8
141: dsp 'source room',S$;wait 1000
```

```
142: wrt 4.5,"DATE:",V$
143: ent "CAL LEVEL SOURCE RM",O
144: ent "CAL LEVEL RECPT ROOM",P
145: 20.06\(273.15+(5/9)(F-32))}A
146: ret
147: "out1":
148: fmt 1,1x,"# of decays",f5.1
149: fmt 2,8f15.5
150: fmt 3,9x,"FREQ",12x,"dB/S",10x,"%E",13x,"T60",12x,"ABS"
151: fmt 6,2/
152: wrt 4.6
153: wrt 4.1,R
154: wrt 4.6
155: wrt 4.3
156: for I=1 to 18
157: .921*H*X[I]/A}Q[I]
158: .161*H/Q[I]}G[I]
159: wrt 4.2,W[I],X[I],S[I],G[I],Q[I]
160: next I
161: wtb 4,10;wtb 4,10;wtb 4,10
162: sprt 1,O,P,V$,D$,S$,N$,G,Q[*]
163: ret
*17391
```

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TRANSMISSION LOSS PROGRAM

```
0: dsp "***TRANSMISSION LOSS TEST***"
1: dim B$[318],C$[8],D$[80],M$[12],N$[6],Q$[1],R$[1],S$[1],T$[2],W$[18]
2: dim A[18],B[18],C[18],D[18],E[18],F[18],G[18],H[18],J[18],K[18],L[18]
3: dim N[18],P[18],Q[18],R[18],S[18],T[18],X[18],Y[18],V[30,18],W[30,18]
4: files ABSDAT,*
5: sread 1,A,C,C$,D$,S$,N$,S,A[*]
6: dsp "INITIALIZE TRAVERSE";stp
7: if S$="A";for M=1 to 91;lcl 7;wait .01;rem 7;next M;wait 5000
8: if S$="A";for M=1 to 91;lcl 7;wait .01;rem 7;next M;wait 5000
9: if S$="A";for M=1 to 71;lcl 7;wait .01;rem 7;next M
10: if S$="B";for M=1 to 81;lcl 7;wait .01;rem 7;next M
11: if A<C;gto 13
12: A-C→E;gto 14
13: C-A→G
14: 100→F[1];125→F[2];160→F[3];200→F[4];250→F[5];315→F[6];400→F[7]
15: 500→F[8];630→F[9];800→F[10];1000→F[11];1250→F[12];1600→F[13]
16: 2000→F[14];2500→F[15];3150→F[16];4000→F[17];5000→F[18]
17: buf "in",B$,3
18: 30→N
19: wrt 717,"OBN?L>M?";wait 1000
20: dsp "SET"
21: wrt 717,"N>";wait 500
22: cll 'TRAVRS';wait 4000
23: cll 'SPL READ';wait 200
24: for J=1 to 18;L[J]→B[J];next J
25: if A>C;for J=1 to 18;E+B[J]→B[J];next J
26: wait 32000;wait 5000
27: for L=1 to 2
28: if L=2;cll 'STRAVRS'
29: wrt 717,"OBN?L>M?";wait 1000
30: dsp "SET"
31: if L=1;lcl 7;wrt 717,"N<";wait 500;gto 33
32: if L=2;lcl 7;wrt 717,"N:";wait 500
33: for H=1 to N
34: if frc(H/2)=0;wait 2000;gto 38
35: wait 5000
36: cll 'TRAVRS'
37: lcl 7;wait 4000
38: cll 'SPL READ';wait 100
39: if L=2;gto 44
40: for J=1 to 18
41: if R[J]-B[J]>10;gto 43
42: cll 'BAGR'
43: next J
44: if L=1;for J=1 to 18;R[J]→V[H,J];next J
45: if L=2;for J=1 to 18;S[J]→W[H,J];next J
46: next H
47: next L
48: rem 7
49: dsp "STATS CALCULATION for 30 TESTS"
50: for H=1 to N
51: if H=1;for J=1 to 18;0→C[J]→E[J]→G[J]→D[J]→Q[J];next J
52: for J=1 to 18
53: W[H,J]-V[H,J]→N[J];N[J]^2→T[J]
54: if A[J]=0;0→S[J];gto 56
55: N[J]+10log(S/A[J])→S[J]
56: next J
57: flt 4
58: for J=1 to 18
59: C[J]+tn^(V[H,J]/20)→C[J]
60: E[J]+tn^(W[H,J]/20)→E[J]
61: G[J]+N[J]→G[J]
62: D[J]+S[J]→D[J]
63: Q[J]+T[J]→Q[J]
64: next J
65: next H
66: for J=1 to 18
67: 20log(C[J]/N)→C[J];20log(E[J]/N)→E[J]
68: G[J]/N→G[J];D[J]/N→D[J]
```

```
69: next J
70: for H=1 to N
71: if H=1;for J=1 to 18;0→X[J]→Y[J];next J
72: for J=1 to 18
73: X[J]+tn^(V[H,J]/10)→X[J]
74: Y[J]+tn^(W[H,J]/10)→Y[J]
75: next J
76: next H
77: for J=1 to 18
78: √((X[J]-N*tn^(C[J]/10))/(N-1))→X[J]
79: √((Y[J]-N*tn^(E[J]/10))/(N-1))→Y[J]
80: next J
81: for J=1 to 18
82: 20log(1+X[J]/tn^(C[J]/20))→X[J]
83: 20log(1+Y[J]/tn^(E[J]/20))→Y[J]
84: √((Q[J]-N*G[J]^2)/(N-1))→B[J]
85: next J
86: cll 'ConfLim'
87: for J=1 to 18
88: H[J]/C[J]*100→K[J];J[J]/E[J]*100→P[J]
89: L[J]/G[J]*100→R[J]
90: next J
91: if N=30;cll '2PRINT'
92: open N$,47
93: assn N$,2,0,X
94: fmt 1,c6
95: sprt 2,I$,S$,S,A[*],G[*],V[*],W[*],C$
96: wrt 4.1,N$
97: dsp N$
98: end
99: "SET":
100: for I=53 to 63;116-I→I;'N'→T$[1,1];char(I)→T$[2,2]
101: wrt 717,T$;wait 2000;'@'→R$;wrt 717,R$;wait 2000
102: red 717,R$;wait 500
103: if num(R$)=63;gto 105
104: 116-I→I;next I
105: ret
106: "SPL READ":
107: dsp "BACKGROUND"
108: if L=1;dsp "RECEIVING ROOM - TEST #",H
109: if L=2;dsp "SOURCE ROOM - TEST #",H
110: wrt 717,"M?C=L?n>";wait 200
111: wrt 717,"M=";H→O$
112: wrt 717,O$;wait 500;red 717,O$
113: if O$=">";jmp 2
114: jmp -3
115: wrt 717,"E?";wait 200
116: buf 'in'
117: tfr 716,'in',302
118: jmp rds('in')#-1
119: wrt 717,"E=";wait 200
120: for J=1 to 18;val(B$[127+7J,K+6])→L[J]
121: if L=1;L[J]→R[J];gto 123
122: if L=2;L[J]→S[J];gto 124
123: if A>C;E+R[J]→R[J];gto 125
124: if A<C;G+S[J]→S[J];gto 125
125: next J
126: ret
127: "BAGR":
128: if R[J]<=B[J];B[J]→R[J];jmp 2
129: 10log(tn^(R[J]/10)-tn^(B[J]/10))→R[J]
130: ret
131: "ConfLim":
132: 1.96/√N→D
133: for J=1 to 18
134: if X[J]=0;gto 136
135: D*X[J]→H[J]
136: if Y[J]=0;gto 138
137: D*Y[J]→J[J]
138: D*B[J]→L[J]
139: next J
140: ret
141: "2PRINT":
```

```
142: fmt 4,1/
143: fmt 1,c80
144: fmt 2,4x,c5,2x,c8
145: fmt 6,4x,c3,2x,f4.1
146: fmt 7,5x,c4,7x,c2,7x,c2,9x,c2,8x,c2,9x,c2,7x,c2,8x,c2,7x,c2,8x,c3,7x,c3
147: fmt 8,5x,c4,6x,c4,5x,c4,7x,c4,6x,c4,7x,c4,5x,c4,6x,c4,5x,c4
148: fmt 9,11f10.4
149: wrt 4.4
150: wrt 4.2,"DATE:",C$
151: wrt 4.4
152: wrt 4.1,D$
153: wrt 4.4
154: wrt 4.6,"H =",N
155: wrt 4.4
156: wrt 4.7,"FREQ","TL","NR","Sn","%E","As","Ss","%E","Ar"," Sr"," %E"
157: wrt 4.8,"(Hz)","(dB)","(dB)","    ","(dB)","(dB)","    ","(dB)","(dB)"
158: wrt 4.4
159: for J=1 to 18
160: wrt 4.9,F[J],D[J],N[J],B[J],R[J],E[J],Y[J],P[J],C[J],X[J],K[J]
161: next J
162: wrt 4.4
163: wrt 4.4
164: ret
165: "TRAVRS":
166: for M=1 to 61;lcl 7;wait .01;rem 7;next M
167: ret
168: "STRAVRS":
169: for M=1 to 91;lcl 7;wait .01;rem 7;next M
170: wait 5000
171: for M=1 to 91;lcl 7;wait .01;rem 7;next M
172: wait 5000
173: if S$="B";for M=1 to 81;lcl 7;wait .01;rem 7;next M
174: if S$="A";for M=1 to 71;lcl 7;wait .01;rem 7;next M
175: ret
*16656
```

TRANSMISSION LOSS CALCULATION

```
0: dsp 'SPECTRUM ANALYSIS OF TL's";wait 1000
1: dsp 'CORRECT D$,G$(23&24) ACCORDINGLY';stp
2: ent 'NO. of CURVES?',C
3: dim N$[6],D$[80],G$[40],S$[1],A[18],G[18],M$[6],B[18],H[18],L$[6]
4: dim F[18],A$[4],B$[4],E$[4],S[C,18],C$[C,50],E[3]
5: dim C[18],D[18],K[18],L[18],F$[6]
6: ent 'FILE NAME',N$;asgn N$,1,0,X
7: files *
8: asgn N$,1;sread 1,D$,S$,S,A[*],G[*]
9: prt D$;spc
10: if C=1;gto 23
11: ent 'FILE NAME',M$;asgn M$,2,0,X
12: files *
13: asgn M$,2;sread 2,D$,S$,A,B[*],H[*]
14: prt D$;spc
15: if C=2;gto 23
16: ent 'FILE NAME',L$;asgn L$,3,0,X
17: files *
18: asgn L$,3;sread 3,D$,S$,B,C[*],D[*]
19: prt D$;spc
20: ent 'REFERENCE PANEL FILE NAME',F$;asgn F$,4,0,X
21: files *
22: asgn F$,4;sread 4,D$,S$,D,K[*],L[*]
23: 'TL FOR [MATERIAL] PANELS, WITH[OUT] DIFFUSERS,'→D$
24: 'MOUNTED IN ROOM [A/B], ROOM [A/B] SOURCE.'→G$
25: for I=1 to C
26: if I=1;'0.54 sq. meter'→C$[I]
27: if I=2;'2.32 sq. meters'→C$[I]
28: if I=3;'3.93 sq. meters'→C$[I]
29: next I
30: for I=1 to 18
31: L[I]+10log(D/K[I])→L[I]
32: G[I]+10log(D/A[I])→G[I];if C=1;gto 35
33: H[I]+10log(D/B[I])→H[I];if C=2;gto 35
34: D[I]+10log(D/C[I])→D[I]
35: next I
36: for J=1 to 18
37: if G[J]>L[J];0→G[J];gto 39
38: 10log(1/(D/S*10^(-G[J]/10)-((D-S)/S)10^(-L[J]/10)))→G[J]
39: if H[J]>L[J];0→H[J];gto 41
40: 10log(1/(D/A*10^(-H[J]/10)-((D-A)/A)10^(-L[J]/10)))→H[J]
41: if D[J]>L[J];0→D[J];gto 43
42: 10log(1/(D/B*10^(-D[J]/10)-((D-B)/B)10^(-L[J]/10)))→D[J]
43: next J
44: for I=1 to 18
45: if C=1;G[I]→S[1,I]
46: if C=2;G[I]→S[1,I];H[I]→S[2,I]
47: if C=3;G[I]→S[1,I];H[I]→S[2,I];D[I]→S[3,I]
48: next I
49: cll 'pgs'(11,11,5,5,5.5)
50: 100→F[1];125→F[2];160→F[3];200→F[4];250→F[5];315→F[6];400→F[7]
51: 500→F[8];630→F[9];800→F[10];1000→F[11];1250→F[12];1600→F[13]
52: 2000→F[14];2500→F[15];3150→F[16];4000→F[17];5000→F[18]
53: cll 'yaxis'(0,45,5,10,5);wait 500
54: cll 'xaxis'(0,21,1)
55: 0→r2;wait 50
56: '.125'→A$;'.250'→B$;'.500'→E$
57: for G=1 to 3
58: fmt 1,c4
59: r2+3→r2
60: cll 'lablxx'(-2,2,r2)
61: next G
62: 9→r1
63: for J=11 to 19 by 3
64: fmt 1,f5.0,z
65: F[J]/1000→I
66: r1+3→r1
67: cll 'lablx'(-4,2,r1)
68: next J
```

```
69: wrt 70417,2,2
70: wrt 70421,A,B
71: cll 'space'(10);cll 'skip'(5);wrt 70412,"FREQUENCY (kHz)"
72: for I=1 to C
73: for J=1 to 18
74: if J=1;wrt 70421,A+(J+1)*U→r1,B-10+S[I,J]*V→r2;gto 81
75: if I=1 and S[1,J]=0;gto 84
76: if I=1;wrt 70420,A+(J+1)*U→r1,B-10+S[1,J]*V→r2;gto 81
77: if I=2 and S[2,J]=0;gto 84
78: if I=2;wrt 70420,A+(J+1)*U→r1,B-10+S[2,J]*V→r2;gto 81
79: if I=3 and S[3,J]=0;gto 84
80: if I=3;wrt 70420,A+(J+1)*U→r1,B-10+S[3,J]*V→r2;gto 81
81: if I=1;cll 'square'(r1,r2)
82: if I=2;cll 'tri'(r1,r2)
83: if I=3;cll 'dim'(r1,r2)
84: next J
85: next I
86: wait 3000
87: wrt 70421,A,B
88: wrt 70425,90
89: for I=1 to 5;wtb 70412,11;next I
90: wrt 70412,"TRANSMISSION LOSS (dB)"
91: wrt 70407
92: wrt 70421,A-65+(3-C),B+45
93: wrt 70417,1.7,2.2
94: wrt 70412,"TRANSMISSION LOSS (dB)"
95: wrt 70421,A-70→X,B+40→Y
96: if C=1;cll 'one'
97: if C=2;cll 'two'
98: if C=3;cll 'three'
99: wrt 70421,A-63,B+36
100: fmt 1,f10.0,f13.1,z
101: fmt 2,f7.0,f11.1,f7.1
102: fmt 3,f6.0,f8.1,f6.1,f6.1,z
103: for J=1 to 18
104: wrt 70421,X,Y-2J
105: if C=1;wrt 70412.1,F[J],S[1,J]
106: if C=2;wrt 70412.2,F[J],S[1,J],S[2,J]
107: if C=3;wrt 70412.3,F[J],S[1,J],S[2,J],S[3,J]
108: next J
109: wrt 70421,A-70→X,B-18→Y
110: wrt 70421,X+7,Y+2;wrt 70412,"LEGEND"
111: for I=1 to C;len(C$[I])→E[I];next I
112: max(E[*])→Q
113: wrt 70421,X,Y
114: wrt 70420,X+18+1.7Q,Y;wrt 70420,X+18+1.7Q,Y-3C-3
115: wrt 70420,X,Y-3C-3;wrt 70420,X,Y
116: if C=1;cll 'd1'
117: if C=2;cll 'd2'
118: if C=3;cll 'd3'
119: wrt 70407
120: wrt 70421,A-35,B-40
121: wrt 70412,D$
122: wrt 70421,A-35,B-43
123: wrt 70412,G$
124: end
125: "pgs":
126: (p3/p1)150→A;(p4/p2)100→B
127: ret
128: "xaxis":
129: (150-A)/(p2-p1)→U
130: wrt 70421,p1U+A,B;wrt 70420,150,B
131: A→p9
132: wrt 70421,p9,B;wrt 70420,p9,B-1
133: p9+p3U→p9
134: if p9<p2U+A;gto -2
135: if p1=0;gto +6
136: A-p3→p9
137: if p9<p1U+A;gto +4
138: wrt 70421,p9,B;wrt 70420,p9,B-1
139: p9-p3U→p9
140: if p9>=p1U+A;gto -2
141: wrt 70421,A,B
```

```
142: 3→p3
143: A→p9
144: p9+p3U→p9
145: wrt 70421,p9,B;wrt 70420,p9,B-2
146: if p9<p2U+A;gto -2
147: ret
148: "yaxis":
149: fmt 1,f2.0,z
150: p4→H
151: (100-B)/(p2-p1)→V;p2V+B→Z
152: wrt 70421,A,p1V+B;wrt 70420,A,100
153: B→p9
154: wrt 70421,A,p9;wrt 70420,A+1,p9
155: for Y=1 to 4
156: wtb 70412,1,8;next Y
157: wrt 70412.1,H
158: p9+p3V→p9
159: if p9<Z;H+p5→H;gto -5
160: if p1=0;gto +5
161: B-p3V→p9
162: wrt 70421,A,p9;wrt 70420,A+1,p9
163: p9-p3V→p9
164: if p9>=p1V+B;gto -2
165: wrt 70421,A,B
166: ret
167: "lablx":
168: wrt 70421,A+p3U,B
169: cll 'space'(p1);cll 'skip'(p2)
170: wrt 70412.1,I
171: ret
172: "lablxx":
173: wrt 70421,A+p3U,B
174: cll 'space'(p1);cll 'skip'(p2)
175: if G=1;wrt 70412.1,A$
176: if G=2;wrt 70412.1,B$
177: if G=3;wrt 70412.1,E$
178: ret
179: "space":
180: if p1<=0;gto +2
181: wtb 70412,32;jmp 2((p1-1)→p1)=0)
182: wtb 70412,8;jmp (p1+1)→p1)=0
183: ret
184: "skip":
185: if p1<0;gto +2
186: wtb 70412,10;jmp 2((p1-1)→p1)=0)
187: wtb 70412,27,10;jmp (p1+1)→p1)=0
188: ret
189: "square":
190: wrt 70421,p1-.45,p2+.45
191: wrt 70420,p1-.45,p2-.45;wrt 70420,p1+.45,p2-.45
192: wrt 70420,p1+.45,p2+.45;wrt 70420,p1-.45,p2+.45
193: wrt 70421,p1,p2
194: ret
195: "tri":
196: wrt 70421,p1,p2+.45
197: wrt 70420,p1-.47,p2-.4;wrt 70420,p1+.47,p2-.4
198: wrt 70420,p1,p2+.45
199: wrt 70421,p1,p2
200: ret
201: "dim":
202: wrt 70421,p1,p2+.45
203: wrt 70420,p1-.45,p2;wrt 70420,p1,p2-.45
204: wrt 70420,p1+.45,p2;wrt 70420,p1,p2+.45
205: wrt 70421,p1,p2
206: ret
207: "d1":
208: wrt 70421,X+3→r1,Y-3→r2
209: cll 'square'(r1,r2);wrt 70420,r1+10→r1,r2
210: cll 'square'(r1,r2)
211: wrt 70421,r1+3,r2;wrt 70412,C$[1]
212: ret
213: "d2":
214: cll 'd1'
```

```
215: X+3→r1;Y-6→r2
216: cll 'tri'(r1,r2);wrt 70420,r1+10→r1,r2;cll 'tri'(r1,r2)
217: wrt 70421,r1+3,r2;wrt 70412,C$[2]
218: ret
219: "d3":
220: cll 'd2'
221: X+3→r1;Y-9→r2
222: cll 'dim'(r1,r2);wrt 70420,r1+10→r1,r2;cll 'dim'(r1,r2)
223: wrt 70421,r1+3,r2;wrt 70412,C$[3]
224: ret
225: "one":
226: wrt 70421,X+7,Y;wrt 70412,"FREQ.(Hz)"
227: cll 'square'(X+36.5,Y+1)
228: ret
229: "two":
230: wrt 70421,X+3,Y;wrt 70412,"FREQ.(Hz)"
231: cll 'square'(X+28,Y+1)
232: cll 'tri'(X+39.5,Y+1)
233: ret
234: "three":
235: wrt 70421,X+1,Y;wrt 70412,"FREQ.(Hz)"
236: cll 'square'(X+21,Y+1)
237: cll 'tri'(X+31,Y+1)
238: cll 'dim'(X+41,Y+1)
239: ret
*2762
```

APPENDIX B

TESTS PERFORMED AT C.B.S.

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TESTS PERFORMED IN REVERBERATION SUITE OF C.B.S.,CONCORDIA U.

TST005	TST005 reference panel rmA receiving with diffusers
TST006	TST006 reference panel rmB receiving with diffusers
TST007	TST007 reference panel rmA receiving without diffusers
TST008	TST008 reference panel rmB receiving without diffusers
tst009	tst009 29in glass inA rmA receiving with diffusers
tst010	tst010 29in glass inA rmB receiving with diffusers
tst011	tst011 29in glass inA rmA receiving without diffusers
tst012	tst012 29in glass inA rmB receiving without diffusers
tst017	tst017 29in gyp inA rmA receiving without diffusers
tst018	tst018 29in gyp inA rmB receiving without diffusers
tst021	tst021 29in gyp 12in baffle inA with diffusers
tst022	tst022 29in gyp 12in baffle inA without diffusers
tst023	tst023 29in gyp 6in baffle inA without diffusers
tst024	tst024 29in gyp 6in baffle inA with diffusers
tst025	tst025 29in gyp inA rmB receiving with diffusers
tst026	tst026 29in gyp inA rmA receiving with diffusers
tst027	tst027 29in glass 12in baffle inA with diffusers
tst028	tst028 29in glass 12in baffle inA without diffusers
tst029	tst029 29in glass 6in baffle inA without diffusers
tst030	tst030 29in glass 6in baffle inA with diffusers
tst031	tst031 29in 2xgyp 12in baffle inA without diffusers
tst032	tst032 29in 2Xgyp 12inbaffle inA with diffuser
tst033	tst033 29in 2xgyp 6in baffle inA with diffusers
tst034	tst034 29in 2xgyp 6in baffle inA without diffusers
tst035	tst035 29in 2xgyp inA roomB recieving without diffusers
tst036	tst036 29in 2xgyp inA roomA receiving without diffusers
tst037	tst037 29in 2xgyp inA roomA receiving with diffusers
tst038	tst038 29in 2xgyp inA roomB recieving with diffusers
tst039	tst039 29in glass 12in baffle in B without diffusers
tst040	tst040 29in glass 12in baffle inB with diffusers
tst041	tst041 29in glass 6in baffle inB with diffusers
tst042	tst042 29in glass 6in baffle inB without diffusers
tst043	tst043 29in glass inB rmB receiving without diffusers
tst044	tst044 29in glass inB rmA receiving without diffusers
tst045	tst045 29in glass inB roomA receiving with diffusers
tst046	tst046 29in glass inB rmA rec with diff.-avg vals only
tst047	tst047 29in gyp 12in baffle inB without diffusers
tst048	tst048 29in gyp 12in baffle inB with diffusers
tst049	tst049 29in gyp 6in baffle inB with diffusers
tst050	tst050 29in gyp 6in baffle inB without diffusers
tst051	tst051 29in gyp inB roomA receiving without diffusers
tst052	tst052 29in gyp inB roomB receiving without diffusers
tst053	tst053 29in gyp inB roomA receiving with diffusers
tst054	tst054 29in gyp inB roomB receiving with diffusers
tst055	tst055 29in 2xgyp 12in baffle inB with diffusers
tst056	tst056 29in 2xgyp 12in baffle inB without diffusers
tst057	tst057 29in 2xgyp 6in baffle inB without diffusers
tst058	tst058 29in 2xgyp 6in baffle inB with diffusers
tst059	tst059 29in 2xgyp inB rmB receiving with diffusers
tst060	tst060 29in gyp inB roomA receiving with diffusers
tst061	tst061 29in 2xgyp inB roomB receiving without diffusers
tst062	tst062 29in 2xgyp inB roomA receiving without diffusers

tst063	tst063 60in glass 12in baffle inA without diffuser	
tst064	tst064 60in glass 12in baffle inA with diffusers	
tst065	tst065 60in glass 6in baffle inA with diffusers	
tst066	tst066 60in glass 6in baffle inA without diffusers	
tst067	tst067 60in glass inA roomA receiving without diffusers	
tst068	tst068 60in glass inA roomB receiving without diffusers	
tst069	tst069 60in glass inA roomB receiving with diffusers	
tst070	tst070 60in glass inA roomA receiving with diffusers	
tst071	tst071 60in gyp 12in baffle inA without diffusers	
tst072	tst072 60in gyp 12in baffle inA with diffusers	
tst073	tst073 60in gyp 6in baffle inA with diffusers	
tst074	tst074 60in gyp 6in baffle in A without diffusers	
tst075	tst075 60ingyp inA roomB receiving without diffusers	
tst076	tst076 60in gyp inA rmA receiving without diffusers	
tst077	tst077 60in gyp inA rmA receiving with diffusers	
tst078	tst078 60in gyp inA rmB receiving with diffusers	
tst079	tst079 60in 2xgyp 12in baffle inA with diffusers	
tst080	tst080 60in 2xgyp 12in baffle inA without diffusers	
tst081	tst081 60in 2xgyp 6in baffle inA without diffusers	
tst082	tst082 60in 2xgyp 6in baffle inA with diffusers	
tst083	tst083 60in 2xgyp inA rmB receiving with diffusers	2A3
tst084	tst084 60in 2xgyp inA rmA receiving with diffusers	2A3
tst085	tst085 60in 2xgyp inA rmB receiving without diffusers	2A3
tst086	tst086 60in 2xgyp inA rmA receiving without diffusers	2A3
tst087	tst087 60in glass 12in baffle inB without diffusers	2B1
tst088	tst088 60in glass 12in baffle inB with diffusers	2B1
tst089	tst089 60in glass 6in baffle inB with diffuser	
tst090	tst090 60in glass 6in baffle inB without diffusers	2B1
tst091	tst091 60in glass inB rmA receiving without diffusers	2B1
tst092	tst092 60in glass inB-rmB receiving without diffusers	2B1
tst093	tst093 60in glass inB rmB receiving with cifffusers	2B1
tst094	tst094 60in glass inB rmA receiving with diffusers	2B1
tst095	tst095 60in 2xgyp 12in baffle inB with diffusers	2B3
tst096	tst096 60in 2xgyp 12in baffle inB without diffuser	2b3
tst097	tst097 60in 2xgyp 6in baffle inB without diffusers	
tst098	tst098 60in 2xgyp 6in baffle inB with difussers	
tst099	tst099 60 in 2xgyp inB rmA receiving with diffusers	
tst100	tst100 60in 2xgyp inB rmB receiving with diffusers	
tst101	tst101 60in 2xgyp inB rmA receiving without diffusers	
tst102	tst102 60in 2xgyp inB rmB receiving without diffusers	
tst103	tst103 60in gyp 12in baffle inB without diffusers	2B2
tst104	tst104 60in gyp 12in baffle inB with diffusers	2B2
tst105	tst105 60in gyp 6in baffle inB with diffusers	2B2
tst106	tst106 60in gyp 6in baffle inB without diffusers	
tst107	tst107 60in gyp inB roomB receiving without diffusers	2B2
tst108	tst108 60in gyp inB roomA receiving without diffusers	
tst109	tst109 60in gyp inB rmB receiving with diffusers	2B2
tst110	tst110 60in gyp inB rmA receiving with diffusers	2B2

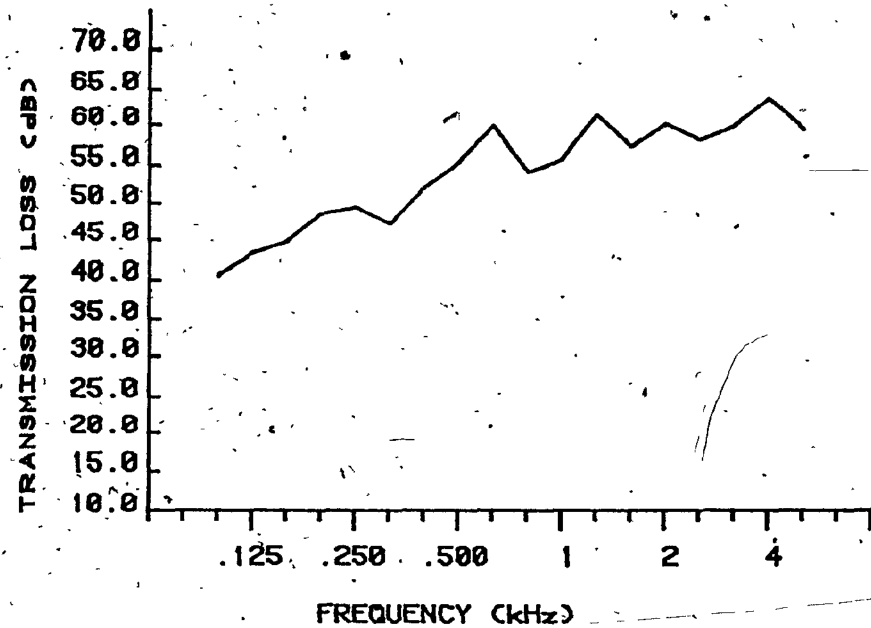
tst113	tst113 78in gyp 6in baffle inA without diffusers 3A2
tst114	tst114 78in gyp 6in baffle inA with diffusers 3A2
tst115	tst115 retest of tst113 with alluminum in place
tst116	tst116 78in gyp 12in baffle inA without diffuser retest tst112
tst117	tst117 78 in gyp 12in baffle inA with diffusers retest 3A2
tst118	tst118 78in gyp inA roomA receiving with diffusers 3A2
tst119	tst119 78in gyp inA roomB receiving with diffusers 3A2
tst120	tst120 78in gyp inA roomA receiving without diffusers 3A2
tst121	tst121 78in gyp inA rmB receiving without diffusers 3A2
tst128	tst128 78in 2xgyp 6in baffle inA with diffusers 3A3
tst129	tst129 78in 2xgyp 6in baffle inA without diffusers 3A3
tst130	tst130 78in 2xgyp 12in baffle inA without diffusers 3A3
tst131	tst131 78in 2xgyp 12in baffle inA with diffusers 3A3
tst132	tst132 78in 2xgyp inA rmA receiving with diffusers 3A3
tst133	tst133 78in 2xgyp inA rmB receiving with diffusers 3A3
tst134	tst134 78in 2xgyp inA rmA receiving without diffusers 3A3
tst135	tst135 78in 2xgyp inA rmB receiving without diffusers 3A3
tst136	tst136 78in glass 12in baffle inA without diffusers 3A1
tst137	tst137 78in glass 12in baffle inA with diffusers 3A1
tst138	tst138 78in glass 6in baffle inA with diffusers 3A1
tst139	tst139 78in glass 6in baffle inA witnout diffusers 3A1
tst140	tst140 78in glass inA rmA receiving without diffusers 3A1
tst141	tst141 78in glass inA rmB receiving without diffusers 3A1
tst142	tst142 78in glass inA rmA receiving with diffusers 3A1
tst143	tst143 78in glass inA rmB receiving with diffusers 3A1
tst144	tst144 78in glass 12in baffle inB with diffusers 3B1
tst145	tst145 78in glass 12in baffle inB without diffusers 3B1
tst146	tst146 78in glass 6in baffle inB without diffusers 3B1
tst147	tst147 78in glass 6in baffle in B with diffusers 3B1
tst148	tst148 78in glass inB rmB receiving with diffusers 3B1
tst149	tst149 78in glass inB rmA receiving with diffusers 3B1
tst150	tst150 78in glass inB rmB recieving without diffuser
tst151	tst151 78in glass inB rmA recieving without diffusers
tst152	tst152 78in gyp 12in baffle inB with diffusers 3B2
tst153	tst153 78in gyprock 12in baffle inB without diffusers
tst154	tst154 78in gyp 6in baffle inB with diffusers 3B2
tst155	tst155 78in gyprock 6in cill in B without diffusers
tst156	tst156 78in gyprock in B rmA receiving witnout diffusers
tst157	tst157 78in gyprock inB rmB receiving without diffusers
tst158	tst158 78in gyprock inB rmA recieving with diffusers
tst159	tst159 78in gyprock inB rmB receiving with diffusers
tst160	tst160 78in 2xgyp 12in baffle inB with diffusers 3B3
tst161	tst161 78in 2xgyp 12in baffle inB without diffusers 3B3
tst162	tst162 78in 2xgyp 6in baffle inB without diffusers 3B3
tst163	tst163 78in 2xgyp 6in baffle inB with diffusers 3B3
tst164	tst164 78in 2xgyp inB rmA recieving with diffusers 3B3
tst165	tst165 2xgyp inB rmB receiving with diffusers 3B3
tst166	tst166 79in 2xgyp in B rm B recieving without diffusers
tst167	tst167 78in 2xgyp inB rmA receiving without diffusers 3B3

APPENDIX C

TL PERFORMANCE OF REFERENCE PANEL

FREQ(Hz)	TL(dB)
100	40.6
125	43.3
160	44.7
200	48.6
250	49.3
315	47.1
400	51.9
500	55.4
630	59.6
800	54.1
1000	55.6
1250	61.2
1600	57.2
2000	60.1
2500	57.9
3150	59.8
4000	63.6
5000	59.3

STC 57



REFERENCE PANEL

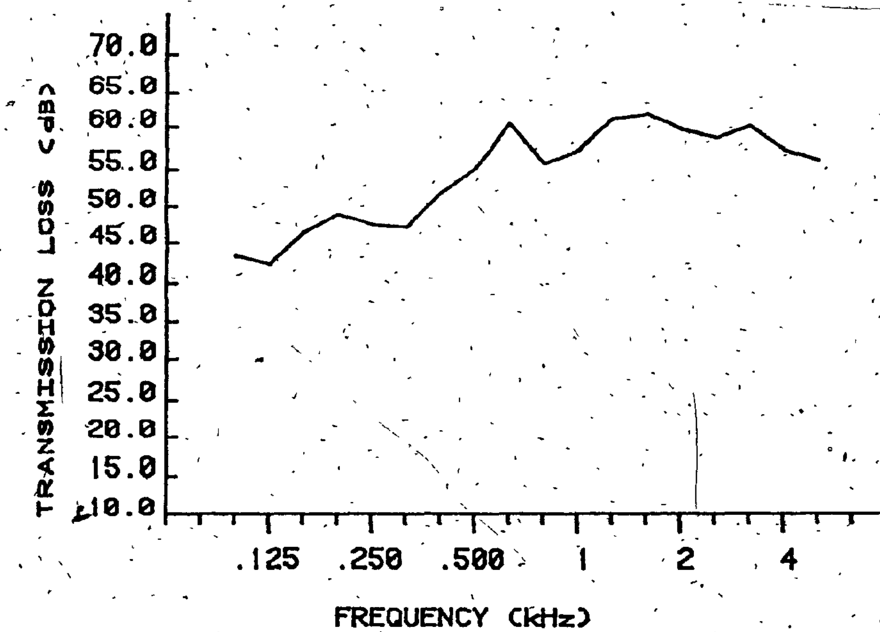
ROOM B RECEIVING WITH DIFFUSERS

PANEL SIZE = 3 X 2.5 METERS

C.1

FREQ(Hz)	TL(dB)
100	43.3
125	42.2
160	46.5
200	48.9
250	47.3
315	46.9
400	51.7
500	55.0
630	60.5
800	55.7
1000	57.3
1250	61.0
1600	61.6
2000	59.7
2500	58.7
3160	60.2
4000	57.3
5000	56.0

STC 57



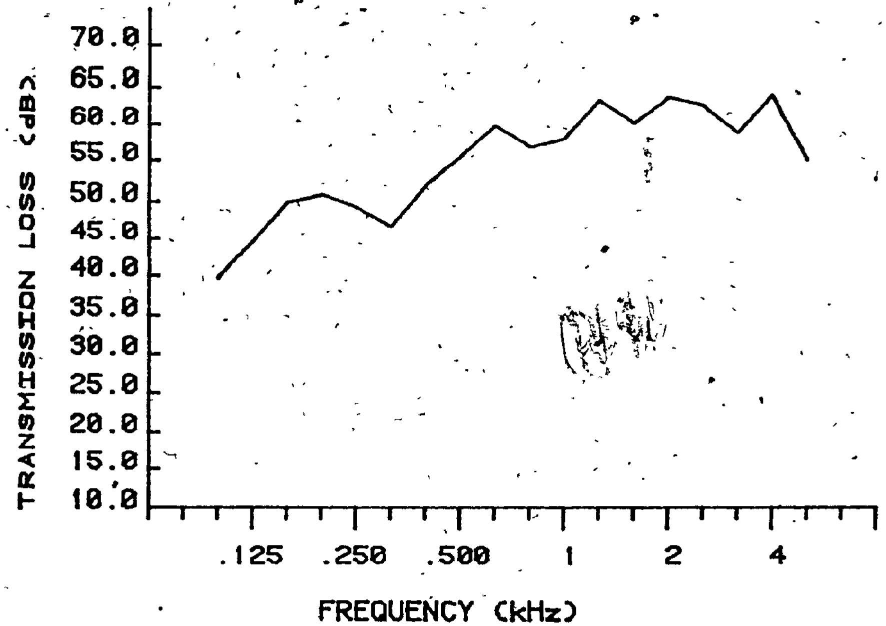
REFERENCE PANEL

ROOM A RECEIVING WITH DIFFUSERS

PANEL SIZE = 3 X 2.5 METERS

FREQ(Hz)	TL(dB)
100	39.7
125	44.5
160	49.9
200	50.6
250	49.2
315	46.5
400	51.9
500	55.4
630	59.6
800	56.6
1000	57.8
1250	63.1
1600	60.1
2000	63.6
2500	62.5
3150	56.6
4000	63.9
5000	54.8

STC 56



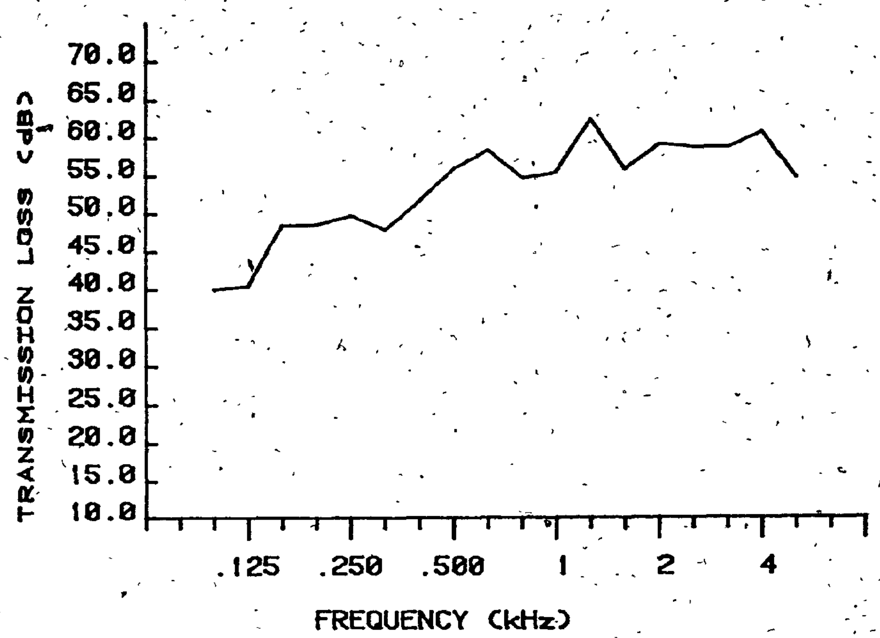
REFERENCE PANEL

ROOM A RECEIVING WITHOUT DIFFUSERS

PANEL SIZE = 3 X 2.5 METERS

FREQ(Hz)	TL(dB)
100	40.0
125	40.4
160	48.4
200	48.6
250	49.7
315	47.9
400	51.6
500	55.8
630	58.2
800	54.4
1000	55.4
1250	62.3
1600	55.7
2000	59.1
2500	58.5
3150	58.5
4000	60.8
5000	54.5

STC 57



REFERENCE PANEL

ROOM B RECEIVING WITHOUT DIFFUSERS

PANEL SIZE = 3 X 2.5 METERS